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HAWAII AGRICULTURAL EXPERIMENT STATION
E. V. WILCOX, SPECIAL AGENT IN CHARGE

PRODUCTION AND INSPECTION OF MILK

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(Under the supervision of A. C. True, Director of the Office of Experiment Stations, United States Department of Agriculture.)

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PREFACE.

Milk is unquestionably the most important of all foods. Infants and young children depend upon it almost exclusively for sustenance and growth. Milk enters into the daily ration of nearly every adult person, particularly in the United States. The daily per capita consumption of milk ranges from one half pint to one pint in different cities. Milk is an ideal food, containing in a readily digestible form and in proper proportions all the elements of a complete, balanced ration. It is universally recognized as peculiarly adapted for the nourishment of children, invalids and convalescents.

Recent investigations have shown the necessity of Federal, State and municipal control of food products. Such control is particularly important in the case of milk for reasons that nearly all kinds of bacteria grow and multiply in milk, that in the ordinary method of handling it is exposed repeatedly to contamination, that milk sugar and casein are easily decomposed into disagreeable or dangerous products, that milk is consumed in largest quantities by children and invalids who are most susceptible to such products, that milk may carry infectious diseases, that milk may be deliberately adulterated or treated with preservatives, and that the consumer can detect none of these abnormal conditions except souring, which is the least harmful of all.

Pure milk is obtained by milking healthy well-groomed cows in clean, sanitary surroundings, in thoroughly cleansed pails, and then cooling the milk to 50° F. or lower, and bottling it or pouring it into tightly closed cans without allowing any contamination to occur from the milkers or other source. Legal phraseology is always ponderous and mystifying and milk inspection regulations may seem unnecessarily complicated. Nevertheless, the only fundamental idea is cleanliness and this idea is easily understood. Healthy cows, healthy attendants, wholesome feeding stuffs, clean water, clean milk utensils, and clean habits are the only requisites. This may be further reduced to two terms, the proper conception of cleanliness and the desire to be cleanly.

An ideal system of milk inspection includes a veterinary inspection of cows, stables, water supply and surroundings; a supervision of milk rooms, milk utensils and methods of cleaning them; supervision of methods of cooling milk and their effectiveness; control of the health and personal habits of the milkers; determination of the temperature at time of delivery, specific gravity, fat, total solids, acidity, presence of preservatives, and bacterial content. The mere laboratory examination of samples of milk taken from dealers is not sufficient.

The cost of milk production has increased in recent years. New equipment to meet the requirements of health officers is an added bur-

den to the milk producer, who may reasonably expect more for his milk after the cost of production has increased. At present the consumer has too little real interest in a pure milk supply. We often hear the milk consumer talk glibly about sanitary milk, and at the same time rebel against paying a higher price for such milk. How can we expect the milk producer to increase his expenses all along the line from the cow to the consumer, if he is compelled to sell his milk for the same price as milk produced more cheaply and under less sanitary conditions? There have been several discouraging experiences along this line. In one instance a philanthropist established a model dairy where milk was produced under ideal sanitary conditions and with a remarkably low bacterial content. The public manifested no interest in the movement and showed no preference for sanitary milk over ordinary milk at the same price. The project was therefore abandoned.

The purpose of the present volume is partly educational and partly practical. It is hoped that the milk producer may gather from it a conception of what constitutes pure milk and definite suggestions as to how to produce such milk. It is even more earnestly hoped that the milk consumer will more clearly realize the value of pure milk and appreciate the extra expense of producing such milk, at least to the extent of being willing to pay more for it than for ordinary milk.

More or less effective regulations for milk inspection have been adopted in nearly every city of the United States. The inspector in enforcing these regulations requires veterinary, engineering and chemical knowledge and much tact as well as practical experience in dairying.

In order that the sanitary regulation of milk may be accomplished most fully it is necessary that the milk producer, the milk consumer and the milk inspector should come to a mutual understanding of one another's problems and difficulties, and cooperate in a cordial and earnest manner. In working to accomplish this purpose the author has reviewed the field of literature on milk and has presented the essential points in the light of personal experience. The dairyman will find a statement of approved methods of feeding and caring for cows, treating their diseases, handling, transportation, sale, refrigeration and pasteurization of milk. The inspector will find a statement of the normal and abnormal properties of milk, the symptoms of bovine diseases, the sanitary requirements of buildings used for dairy purposes, methods of testing and analyzing milk, detecting preservatives and adulterants, and the bacteriological study of milk. The milk consumer will obtain information on the dangers from impure milk, on the nature of the work of the milk inspector, and on what it means to produce pure milk.

Most of the data recorded in this report are drawn from experience on the mainland, in the old dairy sections. Dairy conditions in Hawaii

are different in many respects. The ease with which green fodder can be had the year around is an advantage. In almost every other respect the Hawaiian dairyman is at a disadvantage as compared with the mainland dairyman. Cows give less milk in tropical climates—in Hawaii from four to seven quarts per day. All grains are considerably higher in price. The cultivation of the soil and the raising of green crops are more expensive. The prevalence of the horn fly is a much more serious matter than on the mainland. The most reliable figures on the actual cost of producing milk in Hawaii have been collected by Mr. P. M. Pond, who finds the cost to range between 6 and 9 cents per quart, not including the cost of delivery. Under our present conditions it would seem that the dairyman can not make a reasonable profit on sanitary milk delivered to the consumer at a lower price than 15 cents per quart.

The inspection of dairies carried on under the supervision of Dr. V. A. Norgaard, territorial veterinarian, has been a very efficient means of raising the sanitary standard of our dairies, and of safeguarding the public against the dangers of bacterially infected milk. Dr. Norgaard has brought the intradermal test for tuberculosis to a striking degree of efficiency and reliability.

The vital relation which exists between a sanitary milk supply and the health of infants made it seem desirable to include in this report a chapter on dietetics of milk with reference to infant feeding. This chapter has been written by Dr. Louise Tayler-Jones, a specialist in the diseases of children. There is a peculiar need of careful supervision of the milk supply for children in tropical climates. The recognition of this truth is coming to fruition in the work of the Palama Settlement, and other public-spirited men in Honolulu.

CHAPTER I.

NORMAL MILK.

Milk is the secretion of the udder of the female mammal. In a commercial sense milk means cow's milk unless otherwise specified. The milk of mares, asses, goats and sheep is also used to a limited extent in this country and to a much greater extent in Europe and Asia. Normally milk is secreted only by the female after parturition, but occasionally males, castrated males, virgin females and young animals yield more or less milk. Thus quite frequently buck goats, castrated goats and new-born children produce small quantities of milk. In certain parts of Europe pregnant heifers are regularly milked, but this procedure weakens the heifers and lowers the milk yield after parturition. Virgin female dogs, young colts and mare mules have also been known to give milk. In a few instancese mare mules have given two or three quarts per day continuously for three or four years.

Biology of Milk.

Anatomy of the cow's udder.—The udder is suspended from the pubic region and consists of two halves. The skin over the udder is rather finer than that of the body as a whole. A considerable portion of the skin of the udder is not covered with hair. There is an abundant accumulation of fat in the udder of the heifer and in the connective tissue at either end of the cow's udder. A two-layered wall of connective tissue separates the right and left halves of the udder. There is no special anatomical structure separating the anterior and posterior quarters. Nevertheless each quarter is a distinct part of the mammary gland not communicating with any other quarter by blood vessels, lymph vessels or milk ducts. The independence of each quarter is clearly demonstrated in administering infusions through the teats, and also in the course of mammary diseases. Infusions in one quarter do not penetrate into the other, and disease in one quarter does not affect the milk of any other quarters.

The true secretory parenchyma of the udder is arranged in lobes composed of several lobules which in turn are subdivided into numerous yellowish or yellowish red alveoli. The various parenchymatous structures are held in place and supported by connective tissue in which are found the blood vessels, lymph vessels, nerves and milk ducts. The connective tissue framework also contains fat tissue. With advancing age the connective tissue increases in amount as the

parenchyma decreases. The efferent milk ducts from the individual alveoli gradually unite into larger ducts, finally emptying into tho milk eistern.

Each quarter normally has one teat but occasionally there are supernumary non-functional teats. The milk cistern is partly closed toward the teat by a rosette with 5-8 folds. The mucous membrane of tho milk cistern bears a large number of folds and ridges connecting with one another like grill work. The true seeretory tissue is arranged in the form of glandular tubes enlarged here and there into alveoli. Tho mammary gland is therefore both tubular and acinous. In the virgin heifer the epithelial cells of the glandular tissue grow out into long processes whieh fill up the lumen of the alveoli. During the first pregnancy these processes grow still larger, and braneh into clavate endings. When the epithelial eells prepare for secretion they become finely granular and sharply delimited toward the lumen. Their form is then cylindrical. Small protoplasmic processes which extend into the lumen show a finely granular structure and contain minute fat globules. At the same time the epithelial cells show mitotic ehanges and other forms of activity. Leucocytes collect in the connective tissue, some of them penetrating into the alveolar lumen. With the commencement of secretion the lumen of the alveoli enlarges and becomes filled with fat globules which later coalesce into larger drops. Portions of the eell protoplasm are also discharged into the lumen together with fluid from the cells and blood. In an active stage of laetation the alveolus is darker colored than when at rest. Moreover in a resting condition there is a smaller quantity of secretion, the protoplasma is more often striated, more mitotie figures are to be seen and leucocytes are more numerous. In active lactation the lumen of the alveoli is filled with innumerable fat globules, casein, leucocytes in a stage of fatty degeneration, particles of protoplasm and according to Rievel also amylaceous bodies which are very resistant to both aeids and alkalis.

The blood vessels of the udder are eonnected with the external pudic arteries and external pudic veins. A dense eapillary network surrounds the alveoli and milk ducts. The venous system is so extensively developed in the teats that these organs are to be elassed with erectile structures. The connective tissue carries numerous lymph vessels which surround the alveoli and blood vessels or lie free in the interlobular tissue, and empty into the supramammary lymph glands. The nerves of the udder arise from the lumbar plexus, and the terminal fibrillæ form an extensive network but are without end-organs.

Physiology of milk secretion.—As has been abundantly demonstrated milk can not be considered as a simple transudation from tho blood. Lactalbumin differs from blood albumin. Casein and milk sugar are not found in the blood. The fat globules can not possibly be

derived from the blood, and potash salts predominate in the milk as contrasted with soda salts in the blood. Rauber proposed the hypothesis that the leucocytes become metamorphosed and disintegrated to form the constituents of milk. The leucocytes, however, are never present in sufficient numbers to account for the quantity of milk secreted, and their protoplasm does not contain chemicals which could be modified into the constituents of milk. Milk may properly be considered as the result of liquefaction and fatty degeneration of the mammary parenchymatous cells or parts of these cells. As well stated by Rievel, milk secretion is a specific function of the mammary gland. The chemical bodies which are brought to the gland in the blood are here modified into the constituents of milk and discharged into the lumen of the alveoli.

With regard to the individual elements of milk the water is derived directly from the blood. In the process of transudation this water carries the traces of urea, creatinin and xanthin which are normally found in the milk.

Casein is found nowhere else in the body, but is formed in the udder from the circulating protein furnished by the blood. The transformation takes place in the gland cells. Von Behring, on the other hand, maintains that under the influence of metabolic products in the gland cells the proteid bodies in the blood are modified into casein. According to Basch and others casein is formed by a combination of nucleic acid from the epithelial cell and the blood serum in the glandular alveoli.

Milk sugar rarely occurs elsewhere than in milk. The exact steps by which it is formed are not known. That it may be formed from proteid bodies is apparent from the fact that dogs kept on an exclusive ration of meat yield a milk with a relatively high content of sugar. In the case of herbivora like cows the ration contains abundant material which can readily be transformed into milk sugar. It is well known that the animal body has the power to produce one sugar from another by transformation. Milk sugar may therefore be derived from grape sugar.

A histological examination of the active mammary gland will show that the fat globules of milk come from the gland cells. Milk fat does not arise exclusively from the proteids of the secreting cells. Some of it must be derived from the body fat and also from the food fat. Experiments have shown that food fat may pass over into the milk, but in the udder it undergoes a transformation so that its original characteristics are lost. The iodine number of body fat is different from that of milk fat. They are, therefore, distinct kinds of fat. The fat in colostrum, however, and that in the body tissues seem to be identical According to the extensive investigations of Arnold it appears probable that the secretion of milk fat depends upon modification of the cytoplasm of the mammary epithelial cells without disintegration of

the cells. Fat globules first appear at certain points in the basal portion of the cells near the nucleus. Later secretory vacuoles are formed. Arnold argues that milk fat arises as a synthetic product in the secretory cells of the udder.

The mineral matters which make up the ash of milk are evidently derived partly from the blood and partly from the disintegration of the epithelial cells. The relative proportions in which these minerals exist in the blood are not the same as observed in the milk.

The secretion of milk is to a striking degree under the control of the nervous system. The nervous state of the cow has an influence upon both the quantity and quality of the milk. Manipulation of the teats by the hands or by the calves in sucking sets up a nervous reflex which greatly stimulates the flow of milk. Nervous centers of milk secretion have been found in the brain.

Bacteria in milk.—The bacteriology of milk is discussed in chapter XII. In this connection we may, however, refer to the bacterial content of normal milk. When first secreted in the udder of the healthy cow milk is free from bacteria. In the milk ducts or milk cisterns the milk becomes contaminated with the bacteria which have penetrated from the outside. The nature and extent of this contamination depends upon the circumstances of each case. Most bacteria find in milk ideal conditions for their growth. They multiply rapidly and soon produce souring or other changes after which the milk must be considered abnormal for consumption in a fresh state. Since it is impossible to obtain commercial milk free from bacteria it becomes necessary to set up legal standards for the bacterial content of milk. These standards vary in different States and are discussed below in this chapter. In respect of bacterial content the distinction between normal and abnormal milk is somewhat arbitrary, but for practical and sanitary purposes the distinction has to be drawn. For a discussion of the kinds of bacteria in milk and of their action on milk consult Chapter XII.

Enzymes in milk.—A number of enzymes or unorganized ferments have been found in milk. Stoklasa isolated an enzyme which ferments lactose, decomposing it into carbon dioxide, lactic acid, alcohol and acetic acid. Both aerobic and anaerobic oxydases occur in milk serum without being associated with any of the essential elements. Spolverini found that when an oxydizing ferment was added to the ration the amount of the oxydase was increased in the milk. Experiments with amylase and certain other oxydizing ferments indicate that they do not pass over into the milk. Gillet found a lipase in milk which caused the decomposition of monobutyrin. The action of the lipase was not increased by the presence of bacteria in milk, but was destroyed by a high degree of acidity. The addition of sodium fluoride or chloroform diminished but did not prevent the

action of the ferment. Since this lipase has no action on other glycerids than monobutyrin it was called monobutyrinase. It resists temperatures of 60°-65°C.

Lesperance reports the presence of peptic, tryptic, lipasic and glycolytic ferments in milk. According to Seligmann there are at least three oxydizing ferments in milk. Superoxydase, corresponding to the catalase of Loew, decomposes hydrogen peroxide and may be precipitated with casein by means of an acid. A direct oxydase is also found not requiring the presence of hydrogen peroxide to produce a reaction. Finally milk contains indirect oxydases which are active only in the presence of hydrogen peroxide. The power of milk to decompose hydrogen peroxide is increased by the additions of formalin, as is also the power to give color reactions for enzymes. Raw milk loses its power of reaction by heating, while the milk treated with formalin is only slightly changed in this respect. Boiled milk showing no reaction is again rendered active by treatment with formalin. Various tests used for distinguishing raw and boiled milk lose their value since formalin can restore the reaction lost by heating.

By means of hydrogen peroxide milk may be sterilized without destroying the enzymes present in it. In this way a proteolytic enzyme has been discovered, its action being increased by adding alkali and raising the temperature. The proteolytic action of hydrogen peroxide may easily be distinguished from that of the enzyme. According to some investigators amylolytic enzymes are much more frequently found in milk than are proteolytic enzymes.

Galactase, a proteolytic enzyme of milk has been studied by Babcock, Russell and others. This enzyme is more active in colostrum than in normal milk. The progressive formation of soluble nitrogenous compounds is very striking as milk increases in age. Galactase attaches itself to finely divided particles in suspension. It therefore occurs in larger proportions in cream and separator slime than in milk. Concentrated extracts of galactase prepared from separator slime rapidly oxidize hydrogen peroxide. Galactase is destroyed by heating for 10 minutes at 76°C., or by mercuric chloride, formalin, phenol or carbon bisulphide. The decomposition products formed by galactase are very similar to those of tryptic digestion. Galactase added to milk first coagulates the casein and afterwards redissolves the curd. Babcock and Russell have shown that the main proteolytic changes which take place in the ripening of certain cheeses are due to the action of galactase. The presence of lactic acid diminishes the action of galactase.

Leucocytes in milk.—Leucocytes collect in the connective tissue of the active mammary gland and find their way into the milk. They are always to be found but their numbers vary greatly. Some confusion has been caused by attempts to distinguish arbitrarily between leuco-

cytes and pus cells. Stokes, Bergey and others have been inclined to set up the arbitrary standard for normal milk of 10 leucocytes for one field of a 1-12 immersion lens. More than this number are considered as constituting pus. A number less than ten per field of the microscope is held to be the normal leucocyte count. On the basis of numerous tests Barthel came to the conclusion that milk normally contains great numbers of leucocytes. The reaction with peroxide of hydrogen is attributed to their presence. Cream and separator slime are richer in leucocytes than skim milk, on account of the fact that the leucocytes adhere to the fat globules or other finely divided particles. Barthel considers the leucocytes or an enzyme secreted by them as the cause of the phenomenon observed by Babcock and Russell and by them attributed to galactase.

According to the method of Stewart a diseased condition of the udder is to be suspected if the milk contains more than 100,000 leucocytes per cc. The Doane-Buckley method, however, gives much higher counts than the Stewart method. Ward in testing these methods came to the conclusion that the Doane-Buckley method is the more reliable, and that it is not possible to detect udder disease in cows by the examination of mixed milk for number of leucocytes alone. Ward also insists that the presence of streptococci in milk can not be considered as proof of mammitis, and that the microscopic examination of milk for staphylococci is of doubtful value. An average count of 49,000 leucocytes per cc. was obtained from healthy cows; in one dairy the count was 191,000 per cc. In another dairy one cow showed a count of 4,800,000 per cc. Russell and Hoffman found wide variation in the leucocyte count of cows showing no disease of the udder. These investigators believe that not enough data have been accumulated to formulate a scientific standard for judging milk for the presence of pus. In healthy cows the number of leucocytes ranged between 50,000 and 1,000,000 per cc.. At present it seems impossible to distinguish between pus cells and leucocytes, and the role and significance of leucocytes in milk need further study.

Germicidal substances in milk.—Several investigators, notably Koning, Hunziker and Meyer, maintain that milk possesses certain bactericidal properties. It has frequently been observed that for some time after being drawn milk shows a diminution in the number of bacteria which it contains. This apparent bactericidal power of milk is more pronounced at relatively high than at low temperatures. Koning claims that he has observed a difference in the bactericidal power of the milk of different cows. Colostrom in some instances seems to exercise a strong bactericidal influence. The supposed germicidal action of milk affects both milk bacteria and also various pathogenic bacteria. The soluble proteids of milk such as lactalbumin and lactoglobulin possess no bactericidal action toward coli or typhoid bacilli.

Conn and Stocking do not believe that the decrease frequently ob-

served in the total number of bacteria in milk during the first few hours after milking is due to a germicidal action possessed by the milk, but believe that certain species of bacteria finding milk an unsuitable medium for growth, disappear more or less rapidly, and that when such species are more numerous than those finding milk a suitable medium a decrease in the total number of bacteria may result. Lactic acid bacteria multiply continuously from the outset. Their growth produces an acid reaction in the milk in the presence of which many other species of bacteria can not grow.

The possible passage of specific antitoxic and immunizing bodies from the cow into the milk has been actively discussed in recent years. Opinions are still far apart on this problem. Some investigators like von Behring have argued that the milk of cows affected with disease carries the specific antibodies of the disease and therefore has the effect of immunizing calves or human beings which may drink the milk. The extent to which milk may carry immunizing properties is still an open question.

Physical Properties of Milk.

Color.—Milk is nearly white. In different animals it varies from semitransparent to completely opaque, especially in thick layers. When viewed in thin layers it has a bluish tint. Neither the white nor the blue color is due to a pigment. The blue color is a sort of fluorescence, while the white color is caused by the fact that milk is not a homogeneous fluid but is composed of substances of different refractive indices. The small innumerable fat globules reflect the rays of light in various directions, and few if any of the rays of light penetrate through the milk. The smaller the number of fat globules in the milk the less opaque the sample. The yellowish tint frequently observed in milk is apparently derived from the feed stuffs.

Specific gravity.—In order to detect the possible dilution of milk the specific gravity is determined. In normal milk the average specific gravity is 1.030 at 60° F. and 1.029 at 70° F. If the lactometer spindle floats above 33 it may be assumed that the milk has been skimmed, and if it floats below 29 that it has probably been watered. The specific gravity of normal milk may vary from 1.028 to 1.035; in individual cows it may occasionally sink as low as 1.026, or rise as high as 1.038. In mixed or herd milk the variation is much less. The usual variation in herd milk is from 1.030 to 1.033. The lactometer indicates the specific gravity of milk at a temperature of 60° F. Corrections must be made for other temperatures.

Viscosity.—Viscosity is a term used to denote cohesion or friction between the particles of a fluid. It is determined by noting the time required for a given quantity of the fluid to flow through a tube of known size. The viscosity of milk or cream is greater than that of a

homogeneous liquid of the same specific gravity. The larger the fat globules in a sample the greater the viscosity. The viscosity decreases as the temperature of the milk increases. Thus at the freezing point the viscosity of milk is two times greater than water, while at 30° C. it is only 1.7 times greater. A number of viscometers have been devised which are well adapted to determining the viscosity of milk and cream.

Odor.—The odor of milk often resembles that of the cow's skin, but such is not the case if proper cleanliness has been observed in milking. Milk has a characteristic, indefinable odor apparently depending upon an odiferous body of unknown composition. Aromatic substances sprayed on the cows to keep off flies may lend an odor to the milk. Various drugs and medicines have the same effect. The specific odor of the feeding stuffs used in any particular case is very apparent. Some of these odors are objectionable, while others are barely perceptible and not disgusting. Distillery byproducts, rape, onions, cabbage, turnips and silage may be mentioned among such substances.

Microscopic appearance.—Under the microscope the fat globules are the most conspicuous elements of milk. They vary in size from almost the limit of visibility to .0309 mm. The largest fat globules have been observed in sheep milk. In cows a variation in size is to be noted in different breeds. The fat globules are small in Holsteins, medium-sized in Brown Swiss and large in Shorthorn and Jersey. At the beginning of lactation the globules are largest and gradually become smaller toward the close of the period. Well in comparing these conditions at the beginning and end of lactation found the ratio of fat globules per cmm. to be 103:213, and the ratio of size 458:170. The morning milk has larger fat globules than the evening milk, and in the first streams both the number and size of the fat globules are smaller. In an ordinary sample of milk the largest fat globules are about six times the size of the smallest. There seems to be some relation between the globules of different size. Aikman suggests that the weight of the small globules probably equals that of the large ones.

If leucocytes are present in milk they appear as relatively large cells with nucleus. Several kinds of leucocytes may be recognized. Lymphocytes are small cells with a deeply staining nucleus. Large uninuclear leucocytes are larger with a larger, less deeply staining nucleus and a larger mass of protoplasm. Multinuclear cells show an irregular nucleus or several nuclei or nuclear granules.

Specific heat of milk.—Since milk varies in composition its specific heat varies accordingly. According to Fleischmann's determinations the specific heat of milk averages .874 and of cream .78. Guerin found the specific heat to be .98, and Schnorf found it to range from 1.004 to 1.085 with an average of 1.042. If the last determination be correct it is apparent that more refrigeration is required in freezing milk than in freezing water.

Freezing point of milk.—It has been found that the freezing point of milk lies .54°-.58°C. under that of water. If water is added the freezing point approaches that of water. The cryoscopic test may therefore be used in detecting dilution with water. In tuberculosis, mammitis and various other diseases the freezing point of milk is lowered.

Density of milk.—The maximum density of milk appears at a temperature of —.3°C as compared with 4°C. in the case of water. The expansion coefficient of milk increases with the temperature and also with the increase in solid contents.

Refractive index of milk.—The refractive power of milk varies greatly according to the composition. In normal milk the refractive index ranges from 1.3470 to 1.3515. A minimum of 1.3435 is very rarely observed.

Cohesive power of milk.—At a temperature of 5°C. the cohesion of milk is 100.15 with water at 100. At higher temperatures, however, the cohesive power of milk is less than that of water.

Electrical resistance and conductivity.—The electrical conductivity of milk depends upon the degree of dissociation of the salts which it carries in solution. The resisting power of milk ranges between 180 and 210 ohms. If water is added to milk its resistance is increased. An accurate determination of the amount of dilution can not be made by an electrical test for the reason that the resisting power of water varies with its salt content.

Basis of the methods of creaming milk.—The fat globules are lighter than the milk serum. Consequently the fat is separated by the force of gravity or centrifugal motion. Several methods of separation are in common use. In the shallow pan system the milk is poured into pans to a depth of 2-4 inches and kept at a temperature of 40°-60°F. for 36 hours at the end of which time the cream is as nearly separated as may be by this system. From .5 to 1 per cent of the cream remains in the milk serum. This is due to the fact that some of the fat globules are caught and held by the curdling casein, fibrin or other constituents of the milk. Obviously any fat which is caught in the curd can not rise to the surface. Deep setting consists in placing the milk in Cooley or shotgun cans about 8 inches in diameter and 20 inches deep. If the milk is kept at a temperature of 40°F. it does not curdle so rapidly and the cream rises somewhat more quickly, the process being completed at the end of about 24 hours. When properly operated only about .2 per cent of the cream is lost by this system. The physical basis of the dilution method is the fact that the whole mixture possesses a lower viscosity than undiluted milk and that therefore less resistance will be offered to the rising fat globules. If milk is diluted with an equal quantity of pure cold water the fat will

rise in a few hours after which the water and milk serum may be drawn off from below, leaving the cream.

The centrifugal separator depends for its efficiency upon the same fact as that utilized in separation of cream by gravity, viz. that fat globules are lighter than milk serum. When milk is revolved at high velocity in the bowl of a separator the fat globules remain near the center of the column while the serum and other constituents of the milk are thrown to the outside. The cream and skim milk may therefore be removed by separate tubes in continuous streams. The various makes of separators differ chiefly in the diameter of the bowl, rate of revolution and the fixtures in the bowl. The essential principle, however, is the same in all.

Chemistry of Milk.

Reaction.—The milk of carnivorous animals has an acid reaction. In herbivora the reaction varies being sometimes neutral, sometimes alkaline, sometimes slightly acid and usually amphoteric. Milk with an amphoteric reaction turns blue litmus paper red and red paper blue. According to Soxhlet the amphoteric reaction is due to the presence of two sodium salts of phosphoric acid, one of which is acid and the other alkaline. The exact nature of the amphoteric reaction is not well understood and it has little significance. With some testing papers and coloring matters milk always shows an acid reaction while with other tests the reaction is uniformly alkaline. In most cases the apparent reaction is as much a function of the testing substance as of the milk. The reaction of normal milk, however, is always nearly neutral, being only slightly acid or alkaline. Fresh milk tastes sweet on account of its content of lactose. The lactose is soon broken up into lactic acid and other compounds by the action of lactic acid bacteria after which the reaction is decidedly acid.

Composition—Milk has a very complex composition. The chief constituents of milk are water, fat, milk sugar, casein, lactalbumin, lecithin, cholesterin, citric acid, extractives, salts and gases. Of these water, fat, proteids, milk sugar and salts are most important. Analyses have been compiled showing the content of these substances in milk from mixed and pure herds in various countries. These analyses vary in certain details as is to be expected in a fluid subject to such variations as milk. In general it may be said that milk contains 87 per cent water and 13 per cent solids. An average deduced from 200,000 analyses indicates water 87.10 per cent, fat 4 per cent, milk sugar 4.75 per cent, casein 3 per cent, albumin .4 per cent and ash .75 per cent. The fat may vary from 1 per cent to 12.5 per cent, and the solids not fat from 5 per cent to 10.6 per cent.

Fat.—Milk fat is in a finely divided state and of better flavor than other fats. Like all fats it is made of glycerids composed of glycerine

and a fatty acid. The most important glycerids in milk fat are stearin, palmitin and olein, but there are several others such as butin. butyrin. caproin, caprylin, caprin, laurin and myristin. Stearin melts at 55°C., palmitin at 62.8°C., and myristin at 31°C. Most of the other fats are liquid at ordinary temperatures. The average composition of milk fat is butyrin 3.85 per cent, caproin 3.6, caprylin .55, caprin 1.9, laurin 7.4, myristin 20.2, palmitin 27.7, stearin 1.8, and olein 35 per cent. The proportions of these glycerids vary considerably and the melting point of milk fat is therefore variable, ranging from 29.5° to 33°C. Milk fat is soluble in water and also non-volatile. The density of milk fat ranges from .9307 at 15°C. to .8667 at 100°C., and the specific gravity ranges from .9300 at 15°C. to .8637 at 100°C. The average index of refraction is 1.4566. According to Richmond milk fat mixes with esters, is dissolved by glycerol, all hydrocarbons which are liquid at ordinary temperatures, ether, carbon bisulphide, nitro-benzene, and acetone. Butter fat becomes rancid as a result of hydrolysis, splitting up into fatty acids and glycerol. The latter is oxydized, yielding aldehydes and soluble acids. The fact that the globules of milk fat do not coalesce but remain separate has caused much speculation. Storch has proposed the theory that each globule is surrounded by a membrane of casein or mucoid material. The chemical study of milk has furnished little evidence in favor of this theory and it seems unnecessary to explain the emulsified condition of milk.

Casein.—Casein, or as some writers prefer to call it caseinogen, is the chief albuminoid of milk. Other albuminoids described as occurring in milk are lactalbumin, lactoglobulin, galactin, galactozymase, syntonin, albumoses, fibrin, nuclein, galactase, etc. Casein is found in milk in a fluid condition but is not soluble in water. Sulphur is incorporated in the molecules of casein which, therefore, belongs with the nucleins. According to Kirchner the percentage composition of casein is carbon 53, hydrogen 7.12, nitrogen 15.65, oxygen 22.6, sulphur .78, phosphorus .85. Pure casein is a white, amorphous, tasteless, odorless body, practically insoluble in water, completely insoluble in alcohol or ether, slightly soluble in acids and readily soluble in alkaline solutions. If casein comes in contact with lime it takes up some of it and therefore often contains lime to the extent of 1 per cent. In fresh milk casein is in a colloidal or semidissolved state and is somewhat opaque. If milk is allowed to stand a small portion of the casein is changed into soluble peptones. The curd of milk is composed chiefly of casein which may be coagulated by acids (such as lactic in souring milk), rennet enzyme, trypsine and certain other ferments.

Lactalbumin.—In normal milk lactalbumin differs from blood albumin but in colostrum it is nearly identical with the latter. The average amount of lactalbumin in normal milk is .6 per cent but in

colostrum it is much more abundant. Lactalbumin is soluble in water and is not coagulated by rennet or dilute acids. It is coagulated, however, by a temperature of 70-75°C. Moreover, it is precipitated by alcohol, phosphotungstic acid or tannin. Its composition is not changed by coagulation. Lactalbumin contains no phosphorus but contains more sulphur than does casein.

Lactoglobulin.—This albuminoid is readily soluble in sodium chloride solutions, is coagulated by heat and precipitated by tannin or neutral sulphates. In colostrum it may be present to the amount of 8 per cent but in normal milk there is merely a trace. It appears to be identical with serum globulin.

Galactin or lactoprotein.—This peptone is present in fresh milk to the extent of .13 per cent. According to Richmond galactin is composed of portions of the casein and lactalbumin and their decomposition products.

Other albuminoids.—Galactalzymase, syntonin, albumoses and peptones exist in milk at most in mere traces, and are perhaps not normal constituents but rather decomposition products. Babcock claims to have demonstrated fibrin in milk with a coagulation power one two thousandth part that of blood fibrin. Milk is said to give the guaiac and H_2O_2 test for fibrin. True peptones are apparently not present in normal milk. Nucleon or sarcophosphoric acid was found in milk by Siegfried in the proportion of .09 gm. per liter. The mucoid proteid described by Storch is probably a modified portion of the casein.

Milk sugar.—Milk sugar or lactose is found only in milk. Its composition is $C_{12}H_{22}O_{11} \cdot H_2O$. Under the influence of lactic acid bacteria each molecule of milk sugar breaks up into four molecules of lactic acid. It contains one part of water of crystallization which is not driven off by drying the sugar at a temperature of 100°C. It does not readily dissolve in water or alcohol and is therefore not very sweet. At a temperature of 15°C. about 7.5 gm. is dissolved in 100 cc. of water. Milk sugar dissolves the oxides of lime, lead, copper and mercury. It is not fermented by trypsin, pepsin, rennet, yeast, invertase, or diasase. It is hydrolized into glucose and galactose, however, by lactase which is found in kephir grains. In commercial practice milk sugar is obtained by crystallization after the fat and albuminoids have been removed. The preparation of milk sugar is therefore most profitably combined with the cheese industry.

Mineral constituents.—The ash obtained by burning milk does not truly represent the mineral elements in milk, some of them being thereby changed. While present in small proportion the mineral constituents of milk are very important. They vary in amount less than the other constituents of milk. On an average the ash constitutes about .75 per cent of the milk, varying from .5 to .9 per cent. Söldner gives the following composition of the ash of milk:

Sodium chloride	10.62
Potassium chloride	9.16
Monopotassium phosphate	12.77
Dipotassium phosphate	9.22
Potassium citrate	5.47
Dimagnesium phosphate	3.71
Magnesium citrate	4.05
Dicalcium phosphate	7.42
Tricalcium phosphate	8.90
Calcium citrate	23.55
Lime combined with proteids	5.13

While, however, the total amount of mineral matter in milk varies within very narrow limits the individual mineral constituents vary greatly in amount. Citric acid and lime may be considered as normal constituents of milk. In some samples of milk sulphur has been found to the extent of .043 per cent. Occasionally iron is found in the milk of cows, goats and women. It is commonly believed that a portion of the phosphorus in milk is in organic union with nuclein and lecithin.

Other substances sometimes found in normal milk include acetates, silica, iodine, fluorine, thio-cyanates, amyloid, urea, alcohol, lactic acid, acetic acid, leucin, cholesterin, creatin, xanthin, tyrosin, a coloring matter, an odoriferous substance, oxygen, nitrogen, carbon dioxide and other gases. Recently Biscaro isolated potassium orotate from milk sugar. The enzymes commonly found in milk have been mentioned in discussing its biology.

Factors Influencing the Composition of Milk.

Breed.—The influence of the breed of cow upon the composition of the milk has received a great deal of attention. The results obtained in this study are by no means uniform. There is the greatest variation in respect of composition of milk within the same breed. In general, however, the Guernseys and Jerseys give milk relatively rich in fat, and the Holsteins and Dutch Belted a milk relatively low in fat content. The other breeds stand somewhat intermediate in this respect. In milk tests of breeds attention is chiefly directed to the fat content of the milk. The total solids vary less than the fat. In a test by Lloyd the fat content of the milk was 3.74 per cent in Shorthorns, 5.38 in Jerseys, 5.01 in Guernseys, 3.65 in Red Polls, 4.33 in Kerries and 3.97 in crosses. In the same test the total solids were highest in Jerseys and lowest in Shorthorns. In a test in Wisconsin the milk yield was highest in Holsteins followed by Brown Swiss, Shorthorn, Guernsey, Ayrshire, Dutch Belted, French Canadian, Red Polled, Jersey, Polled Jersey and Devon.

In a test of fat percentage the Jersey stood at the head followed by Guernsey, Polled Jersey, Devon, French Canadian, Ayrshire, Red Polled and Shorthorn. A comparative test in Toronto placed the

breeds in the order Aberdeen Angus, Hereford, Shorthorn, Ayrshire. In a test in New York the Guernsey stood at the head followed by Jersey, Ayrshire, Shorthorn and Holstein. It is apparent from these few figures that the breed is not as important as the individual merit of the cow.

Age of cow.—In Algau it has been found that the yield and fat content of milk increase up to the fifth calving after which both decrease. The results of extended observations in Scotland covering 1,340 cows indicate that in mixed herds cows 15 years old give milk with a fat content of 3.74 per cent, and cows two years old 3.83 per cent. This difference is not striking. No regular increase or decrease was found in cows of ages intermediate between two and 15 years. A series of milk records kept for five years shows that young cows give milk richer in fat, while older cows give more milk. It may be safely asserted that any individual cow yields as rich milk as a heifer as she will as a mature cow.

Period of lactation.—At the beginning of lactation the amount of milk is high and the fat content low. During the first few days the milk is known as colostrum and has a very different composition from normal milk. The composition of colostrum is about as follows: albumen 6.77 per cent, fat 3.57, sugar 4.68, mineral salts .82 and water 84.16 per cent. The solids of colostrum may be as high as 20 per cent. In the course of the period of lactation the yield gradually diminishes while the fat content rises. After a few weeks the fat content may fall slowly till near the end of the period of lactation when the fat content becomes abnormally high and the yield very low. Just before the cow is dried off the fat percentage may be so high as to render the milk almost abnormal. The percentage of the other solids is not affected. The ash content of the milk remains practically constant during the whole period of lactation. Variation is greatest in the fat and less in the milk sugar and proteids. An increase or decrease in the fat content is usually accompanied by an opposite change in the content of protein and milk sugar. Dividing the period of lactation into three equal parts the sugar is 10-12 per cent greater during the first months of the second period than in the first period, but later it slowly diminishes. The total amount of fat and casein of the second period follows closely the milk yield. Van Slyke found the per cent of fat highest during the first month of lactation. In the second month it dropped considerably in the richest milk. The total yield of milk increases, however, so that the greatest fat yield is obtained during the second and third months. As the period of lactation progresses there is more and more fat lost in the skim milk. In some cases this loss of fat is not observed.

Individuality.—The greatest differences are observed in the fat content of the milk of individual cows of the same breed. Thus Fleischmann in a continued study of this point in 18 cows of the same

breeding and subjected to the same conditions found that the fat content of the milk varied from 2.66 per cent to 3.88 per cent. Wherever this matter has been investigated it has been found that the individual peculiarities of the cow are of the highest importance in determining the fat content of the milk. The fat in the milk of one cow may be very high while in another it may be low with no assignable reason except the individual nature of the cows concerned The tendency to produce milk of a high fat content is in a pronounced degree hereditary. The tendency is not always inherited from the mother but a bull with an excellent milking ancestry is of great influence in increasing the fat content of the milk of his offspring as compared with the grade cows to which he is bred.

Manner and time of milking.—During the course of each milking there is an increase in the fat content. By separating one milking into 17 portions Shov found that the fat content increased from .7 to 8.9 per cent, or in one case to 9.6 per cent. Four characteristic periods were observed in the same milking. In the first the milk contained less than 1 per cent of fat, in the second period there is a sudden rise of fat content, in the third period the fat remains at the high point, while in the last sample there is a great increase in the fat. In certain cows extremes of .8 and 13 per cent were observed.

Differences have been observed in the fat content of morning's and evening's milk. Fleischmann in a long series of tests found a fat content of 3.26 per cent in morning's milk and 3.18 in evening's milk as compared with 3.22 for the day. In other investigations, however, the content of fat, protein and ash has been higher in the evening and the content of milk sugar lower. Gilchrist found the morning's milk sometimes below the market standard in fat and recommends three milkings per day to prevent this occurrence. Beach found that by milking three times a day the total yield of fat was increased 14 per cent. Slight inequalities in the intervals between milking cause no serious effeft upon the quality of the milk so long as the changes are not sudden. Great inequalities in the intervals may reduce the fat percentage. A change from a narrow to a wide ration is likely to diminish the fat content of the morning's milk more than that of the evening. If all the grain is fed in the evening the fat content of the morning's milk is increased in most but not all cases. If the intervals between milkings are very unequal the larger milk yield and lower fat percentage follow the longer interval. Stokes believes that cows reassimilate some of the fat for their own uses if the milk is allowed to remain too long in the udder. In one test of three milkings per day the fat percentage was highest at noon and lowest in the morning. An experiment in milking cows four times per day showed that the yield of fat is thereby increased but the percentage diminished. The advantages of milking more than two times per day are not sufficient to justify the procedure.

The foremilk is not rich in fat and has a high bacterial content.

From 4 to 10 streams should therefore be discarded. The strippings contain the highest fat percentage. Much fat is therefore lost if the cows are not thoroughly stripped. The efficiency of milkers differs greatly in this respect. The Hegelund method of milking, described in Chapter VI, has been highly recommended by Woll for increasing the amount of fat obtained. The composition of the aftermilk obtained by the Hegelund method is essentially the same as that of the ordinary strippings.

Lepoutre found that when each quarter of the udder was milked separately the fat percentage was highest in the first quarter milked, and lowest in the last quarter. If two quarters were milked simultaneously the fat content of this milk was higher than that of the milk from the other two quarters. Ingle found appreciable but not constant differences in the composition of the milk from different quarters of the udder. Carlyle reports that a constant change of milkers so long as none of them is a stranger to the cows results in a slightly increased fat percentage. So far as milking machines have been tested they seem to have little or no effect upon the composition of the milk.

Exercise, work, and fatigue.—In experiments carried out by Hills cows driven and transported by rail gave milk with a low fat content on the next day but for the following few days the fat content was above normal. The percentage of solids not fat was not affected. Morgan tried the experiment of working cows one or two hours daily. The percentage of fat was thereby increased while the content of milk sugar decreased greatly. A reasonable amount of exercise for the cows has little effect on the composition of the milk.

Spaying.—If cows are spayed during a period of lactation this period may be extended for a year or two beyond the usual term. The milk yield gradually diminishes and its composition varies. As a rule the percentage of fat, milk sugar and casein is increased. Spaying may cause great temporary fluctuations in the composition of the milk after which it returns to its normal character.

Estrum.—Milk may or may not show alterations in composition during estrum. Malpeaux noted a slight diminution in fat. Snorf found that estrum had no effect on the electrical conductivity of milk but lowered the freezing point. The percentage of fat may be temporarily increased but soon falls to normal Doane made determinations of the total solids, fat, protein, casein and sugar in the milk of 5 cows before, during and after the periods of heat. In no case was the percentage of fat lower than normal during the period of heat, and in only two instances was there any increase. No variations were observed in the other constituents nor in the temperature of the cows.

Weather.—Sudden climatic changes and unpleasant weather are more likely to affect the amount than the composition of the milk. The Essex County council of England found no evidence that exces-

sively dry or wet seasons had any influence on the quality of milk. Stokes, however, traced some abnormal milk in London to farms where the cows were subjected to drouth and excessive heat. The total solids in the milk amounted to 12.6 per cent. Crowther found that extremes of temperature tend to cause a decrease in the fat content of milk. After studying this matter Dymond states: "Throughout this experiment the considerable variations in fat and solids have not been to any great extent due to alterations in food or weather or to any external conditions under which the cows were kept and which the dairy farmer could control. The important point is to recognize that these changes are continually taking place but since they are not usually dependent on external conditions but on the idiosyncrasies of each cow, almost complete uniformity can be obtained by mixing the milk of a sufficient number of cows."

Seasons.—There is little or no difference in seasons as to the quality of the milk. Richmond found the lowest fat content in May and June and the highest in October and November. These differences may have been due to other factors and are not uniformly observed. Other things being equal there is little difference in the average quality of the milk during a whole period of lactation whether the cow calves in the spring or fall.

Disease.—In case of any serious disease the milk should be considered unfit for food. The changes produced in milk by the various diseases are discussed in Chapters III and XII.

Excitement.—Under the influence of worry, excitement or fright cows may give milk of a fluctuating quality. At times the fat content is as low as 1.8 per cent, at other times as high as 7 per cent. The other solid constituents are less affected than the fat.

Feed.—It has long been the dream of dairymen to devise a ration by means of which the fat content of the milk could be greatly increased. This achievement seems to be quite impossible. The results of hundreds of experiments along this line indicate that it is impossible to increase materially or permanently the fat yield of a cow by changes in the amount or character of the ration, except in so far as the increase in the total yield of milk increases simultaneously the total fat yield. The percentage of fat is not thereby affected. Woll found that "the food of the dairy cow influences the quality of the milk produced to this extent that the cow will yield a maximum flow of milk of the highest fat content which she is capable of producing on rations relatively rich in nitrogenous substances." Wing and Foord experimented with a herd of cows which had been previously poorly fed and cared for. By feeding them an abundant ration easily digestible and rather nitrogenous in character and continued through two years an average increase of .25 per cent of fat was obtained. This was accompanied by an increase of about 50 per cent in the total amount of milk fat produced. With cows which have been well fed, however, a

change works no permanent effect on the quality of the milk. While it is impossible to increase the fat or other constituents of milk indefinitely or permanently, the ration nevertheless exercises appreciable effects upon the composition of the milk. Morgan demonstrated that to a certain extent food fat exerts an invariably favorable influence upon the production of milk fat, and that fat should not be omitted from the ration of dairy cows. A few instances of specific effects of rations upon the composition of the milk may be mentioned. In general the cows which consume the most food produce the most fat. In one case the discontinuance of silage caused a slight increase in the acidity of the milk. If calcium phosphate is added to a ration which already contains sufficient mineral matter for the ask of milk, an increase in the phosphate content of the ash is noted. Mayer found that butter made from cows which were fed 4 pounds of sugar per day had a low melting and solidifying point and the volatile fatty acids were increased. In many cases great changes in the mineral elements of the ration have caused no corresponding changes in the composition of the milk.

Milk fat is derived from carbohydrates, fat and protein in the food and from body fat. The addition of large quantities of fat to the ration may cause a marked increase in the fat content of the milk for a time or to a certain degree. Beyond this point it may produce the opposite effect. The use of the oils obtained from cottonseed, linseed, corn and various other feeds may have a temporarily good effect upon the fat content of the milk. At the same time the sugar and proteids as a rule remain without change. If a ration containing much oil is used the milk at first shows an increase in fat but soon returns to a normal condition. In rare cases the peculiar properties of the food fats can be recognized in the milk fat when the former were fed to excess. For the most part, however, the food fat loses its individuality in the mammary gland. A change from pasture to dry feed or vice versa may increase or decrease the fat percentage. Lindsey found that feeding corn oil reduced the saponification of the milk 10 points and the Reichert-Meissl number 3½ points, and raised the iodine number 9 points. The melting point of the milk fat was not changed. In experiments with sheep Gogitidse estimated that as much as 33 percent of the constituents of linseed oil passed directly into the milk. The iodine number of the milk fat was rapidly increased but soon fell to the normal after the oil was omitted from the ration.

Slight temporary effects are produced on the composition of milk by almost any change in the ration. The essential oils or aromatic substances in the feed may be detected in the milk. The mineral constitution of the feed affects the ash of the milk. But these as well as the effects of other feeds mentioned above are temporary and non-cumulative. The best system of feeding consists in the use of a well balanced ration of medium ratio.

Freezing.—In freezing the solid constituents of the milk are forced out (with the exception of the fat) and the fluid portion contains more casein, sugar and ash than the ice milk. If a large can of milk is frozen into ice the upper layer contains almost all of the fat, while the central and lower portions contain most of the sugar and casein. The extent of the dissociation of the elements of milk in freezing depends upon the size of the vessel in which it is frozen. For a further account of the effect of freezing on milk see Chapter VIII.

Shelter and care of cows.—In comparing stabling with turning out to pasture at night the higher fat percentage is sometimes obtained from the cows on pasture and sometimes from those in the stable. If cows are exposed to very cold weather the fat content may be lowered until the cows become accustomed to the change. Light and well ventilated stables are more favorable to the health of the cows than dark and poorly aired stables but within the limits of health the effect upon the composition of the milk is scarcely noticeable. Similarly changes in watering and grooming the cows appear to have no direct effect upon the quality of the milk.

Dehorning.—In Arkansas dehorning cows in lactation produced no change in the composition of the milk. Lane also failed to note any change in the solids of the milk as a result of dehorning, but the yield was reduced.

Size of the cows.—Linfield found no correlation between the weight of the cow and the composition of the milk. In Scotland small cows were found to give milk of a slightly higher average fat content than large cows.

Gestation.—Most cows are pregnant during a large part of the period of lactation. The only observed effect of gestation upon the quality of the milk is a diminution of the phosphoric acid and lime up to the time of calving.

Daily variation.—Variations are observed from day to day in the composition of the milk of individual cows. These variations are to be attributed to one or more of the factors mentioned above. The daily range of variation in total solids may be 2 or 3 per cent. In the herd milk of large dairies Siegfeld found the daily variation in the fat content to range from .1 to .3 per cent and not to exceed .45 per cent for the entire year. In terms of cubic centimeters of decinormal sodium hydroxide required to neutralize 100 cc. of milk the acidity may show differences of 1 or 2 cc. from day to day. The daily variation in the fat content of the milk of individual cows is sometimes as high as 3 per cent.

Mixing the milk.—In herd milk the daily variation in composition is very slight. This is due to the fact that the variation in different cows is not simultaneously in the same direction. The variations in the different cows therefore neutralize one another and the result is a uniform mixed milk. Radical variations in the composition of the

mixed milk of a herd "should be viewed with suspicion as indicating either mistakes in testing or gross mismanagement of the herd."

Drugs.—As will be indicated in Chapter II various drugs and medicines may affect the quality of the milk by lending their specific odors and flavors. Drugs are readily excreted with the milk.

Method of drawing from the can.—Since the cream begins to rise as soon as the milk is drawn from the udder, it is necessary that the milk in a delivery can be stirred in order that the different portions removed at different times may have a uniform composition. Bitting found that the fat content of samples of milk drawn from the bottom of a can varied from 1 to 4.4 per cent, while dipped samples had a uniform composition.

Legal Standards for Normal Milk.

In order that milk inspectors may have some basis upon which to proceed in determining what are normal and what abnormal samples of milk it is necessary to establish legal standards. In the following table the standards adopted in the various states of this country are given:

	Total Solids.	Solids Not Fat.	Fat.	
United States		8.5	3.25	
California		...	....	
Colorado		...	....	
District of Columbia		9	3.5	
Georgia		8.5	3.5	
Hawaii	11.5	...	2.5	
Idaho		8	3	
Illinois	12	...	3	
Indiana		9	3	
Iowa	12.5	...	3	
Kentucky	12	...	3	
Maine	12	...	3	
Maryland	12.5	...	3.5	
Massachusetts	12-13	9-9.3	3-3.7	
Michigan	12.5	...	3	Sp. Gr. 1.029-33
Minnesota	13	...	3.5	
Missouri	12	8.5	3.25	
Montana	12	9	3	
Nebraska		...	3	
New Hampshire	13	9.5	3.5	
New Jersey	12	...	....	
New York	12	...	3	
North Carolina	12	8.5	3.25	
North Dakota	12	...	3	
Ohio	12	...	3	

	Total Solids.	Solids Not Fat.	Fat.
Oregon	12	9	3.2
Pennsylvania	12	...	3
Porto Rico	12	...	3
Rhode Island	12	...	2.5
South Carolina		8.5	3
South Dakota	13	...	3
Utah	12.5	...	3
Vermont	12	8.5	3.25
Washington		8	3
Wisconsin		8.5	3
Wyoming	11.5-12	...	2.4

These standards of composition are supposed to be applied to the mixed milk of a herd. If rigidly applied to the milk of a single cow it might be necessary to condemn the milk on certain days as below standard.

Market Milk.

One of the most important points to be considered with regard to market milk is its bacterial content. In actual samples of market milk taken in cities the bacterial content has been found to vary from a few hundred per cc. to 600,000,000 or even more per cc. It is an exceedingly difficult matter to fix a standard for the bacterial content of milk. A standard once adopted has to be qualified in many ways. Pathogenic bacteria can not be tolerated in milk. Even the most harmless lactic acid bacteria will sour the milk in a short time unless it is kept at a low temperature. A high bacterial content indicates unsanitary conditions at the farm where the milk is produced, or carelessness in handling and delivering the milk. Perhaps the best plan thus far suggested for the regulation of the bacterial content of market milk is that recommended by a milk conference in the District of Columbia. Three commercial grades or classes of milk are to be recognized as follows:

Class 1. **Certified milk.**—The use of this term should be limited to milk produced at dairies subjected to periodic inspection and the products of which are subjected to frequent analyses. The cows producing such milk must be properly fed and watered, free from tuberculosis, as shown by the tuberculin test, and from all other communicable diseases, and from all diseases and conditions whatsoever likely to deteriorate the milk. They are to be housed in clean stables, properly ventilated, and to be kept clean. All those who come in contact with the milk must exercise scrupulous cleanliness, and such persons must not harbor the germs of typhoid fever, tuberculosis, diphtheria, and other infections liable to be conveyed by the milk. Milk must be drawn under all precautions necessary to avoid infection, and be immediately strained and cooled, packed in sterilized bottles, and kept at a temperature not exceeding 50°F. until delivered to the consumer. Pure water, as determined by chemical and bacteriological examination, is to be provided for use throughout the dairy farm and dairy. Certified milk should not

contain more than 10,000 bacteria per cubic centimeter, and should not be more than 12 hours old when delivered. Such milk shall be certified by the health officer of the District of Columbia.

Class 2. **Inspected milk**.—This term should be limited to clean raw milk from healthy cows, as determined by the tuberculin test and physical examination by a qualified veterinary surgeon. The cows are to be fed, watered, housed, and milked under good condi tions, but not necessarily equal to the conditions provided for class 1. All those who come in contact with the milk must exercise scrupulous cleanliness, and such persons must not harbor the germs of typhoid fever, tuberculosis, diphtheria, and other infections liable to be conveyed by the milk. This milk is to be delivered in sterilized containers, and is to be kept at a temperature not exceeding 50°F. until it reaches the consumer. It sball contain not more than 100,000 bacteria per cubic centimeter.

Class 3. .**Pasteurized milk**.—Milk from tbe dairies not able to comply with the requirements specified for the production of milk of classes 1 and 2 is to be pasteurized before being sold, and must be sold under tbe designation "pasteurized milk." Milk for pasteurization shall be kept at all times at a temperature not exceeding 60°F. while in transit from the dairy farm to the pasteurization plant, and milk after pasteurization shall be placed in sterilized containers and delivered to the consumer at a temperature not exceeding 50°F. All milk of an unknown origin shall be placed in class 3 and subjected to clarification and pasteurization. No cow in any way unfit for the production of milk for use by man, as determined upon physical examination by an autborized veterinarian, and no cow suffering from a communicable disease, except as specified below, shall be permitted to remain on any dairy farm on which milk of class 3 is produced, except that cows which upon physical examination do not show physical signs of tuberculosis may be included in dairy herds supplying milk of tbis class, although tbey may have reacted to the tuberculin test.

This milk is to be clarified and pasteurized at central pasteurization plants, which shall be under the personal supervision of an officer or officers of the health department. Tbese pasteurizing plants may be provided either by private enterprise or by tbe District Government, and shall be located within the city of Washington.

By tbe term "pasteurization," as used herein, is meant the heating of milk to a temperature of 150°F. or 65°C. for 20 minutes, or 160°F. or 70°C. for 10 minutes, as soon as practicable after milking, in inclosed vessels, preferably the final containers, and after such heating immediate cooling to a temperature not exceeding 50°F. or 10°C.

No milk sball be regarded as pure and wholesome wbich, after standing for two hours or less, reveals a visible sediment at the bottom of the bottle.

No dairy farm shall be permitted to supply milk of a higher class than the class for which its permit has been issued, and eacb dairy farm supplying milk of a specified class shall be separate and distinct from any dairy farm of a different class; the same owner, however, may supply different classes of milk, providing the dairy farms are separate and distinct, as above indicated."

Other points are also to be considered in determining the standard of market milk. The variation in the number of leucocytes in milk will be discussed in Chapter II and XII. Apparently we are not yet in a position to set up a standard for the leucocyte count of milk. An analysis of 291 samples of market milk in Chicago showed that 25 per cent were below the legal standard of 3 per cent of fat and 30 per cent

were below the standard of 12 per cent of solids. Only 1.4 per cent of samples showed less than 50,000 bacteria per cc. In various cities of Pennsylvania 18 per cent of milk samples were below standard in fat content, and 37 per cent of the samples showed less than 11 per cent of total solids. In market milk the common ratio of sugar, proteids and ash is 13:9:2. In Norway an analysis of about 15,000 samples for each month of the year showed a variation in fat content of 3.3 to 3.6 per cent. The average fat content for 53,000 samples was 3.52 per cent. Richmond found rather more fat in milk from farms on cretaceous formations than from those on sandstone and clay. The usual legal standard for the temperature of milk when delivered to the consumer is 50° F., and no clean milk will spoil in handling and delivery if kept at this temperature.

Commercial Forms of Milk.

The trade has found it desirable to treat milk in various ways for special purposes. Definitions are given below of some of these specially prepared milks:

"The following notes are offered in the nature of explanations of certain terms whicb, though very frequeutly heard among dairymen and regularly met with in dairy literature, are nevertheless often nsed inaccurately and sometimes in a way intentionally misleading. The many terms, such as aerated milk, filtered milk, etc., which are everywhere well understood are not included. Other terms, such as malted milk and lacto preparations, are omitted because they apply to manufactured food products rather than to forms of milk.

Standard milk.—The variable nature of milk makes it impossible to state without chemical analysis the quantity of fat or other constituents to be found iu any given sample. While numerous factors such as the breed of cows and the stage of lactation affect the composition of the milk, the variations, nevertheless, are within limits capable of being defined with sufficient accuracy and fairness for practical purposes. Nearly every country has found it necessary to establish in one way or another certain minimum requirements. Milk to be considered unadulterated in Great Britain, for instance must contain 3.5 per cent of milk fat and 8.5 per cent of solid matter other than fat. In this country the requirements vary in the different States. In matters concerning the National Government, milk in order to be designated as standard must conform to the following definition proclaimed by the Secretary of Agriculture:

'Milk is the fresh, clean, lacteal secretion obtained by the complete milking of one or more healthty cows, properly fed and kept, excluding that obtained within fifteen days before and ten days after calving, and contaius not less than eight and one-half (8.5) per cent of solids-not-fat, and not less than three and one-quarter (3.25) per cent of milk fat.'

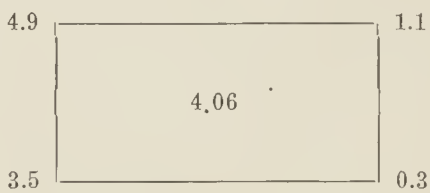
Standard milk is therefore milk which conforms to certain requirements. These are commonly but not always of a chemical nature. In some cities bacteriological standards have been established. These specify usually a maximum number of bacteria per cubic centimeter allowable in milk offered for sale.

Standardized milk, Blended milk.—These terms are applied to milk which has been so modified as to contain a definite amount of one or more of its constituents. The most important and at the same time the most variable constituent is fat. To standardize milk as regards

fat it is simply necessary to add or remove a certain amount of this constituent or to add or remove a certain amount of skim milk. Detailed directions for this purpose are given in Bulletin 75 of the Illinois Station. To cite an illustration from this bulletin, 1,600 pounds of milk containing 3.2 per cent of fat may be standardized to 4 per cent of fat by removing 320 pounds of skim milk. A simple method of determining the amounts of skim milk and whole milk, or of milks containing different percentages of fat which should be mixed in order to secure a product having a desired fat content is given by Prof. R. A. Pearson in a reading-course bulletin of Cornell University.

Draw a rectangle and write at the two left-hand corners the percentages of fat in the fluids to be mixed, and in the center place the required percentage. At the upper right-hand corned put the number which represents the difference between the two numbers standing in line with it—i. e., the number in the center and the one at the lower left-hand corner. At the lower right-hand corner put the number that represents the difference between the two numbers iu line with it. Now let the upper right-hand number refer to the upper left and the lower right hand to the lower left, then the two right-hand numbers show the relative quantities of the fluids represented at the left-hand corners that must be combined to give a fluid of the desired standard which is represented in the center. * * *

If it is wanted to mix the milks from two dairies testing 4.9 per cent fat and 3.5 per cent fat to produce a 4.6 per cent milk, the diagram shows these milks must be mixed in the proportion of 1.1 to 0.3 or 11 to 3. Thus:



If we have 120 pounds of the 4.9 per cent milk we must mix with it 32.7 pounds of 3.5 per cent milk, as is shown by this proportion: 11:3::120:32.7.

Modified milk, Humanized milk.—These terms are applied frequently to cow's milk specially prepared for infant feeding. The most important difference between cow's milk and human milk lies in the proteids or nitrogenous constituents which are greater in amount in cow's milk. By allowing a cow's milk to stand for several hours, taking the top portion, and diluting this with water with the addition of milk sugar, a product may be obtained which corresponds in percentages of fat, proteids, and milk sugar to human milk. The modifications which have been suggested and the ways of making them are very numerous.

Certified milk.—This term, though registered as a trade-mark in 1904, is now quite generally used with reference to milk produced and handled under conditions approved by some responsible organization such as a medical society. An organization of this kind exercises supervision over the health of the cows, the cleanliness of the dairy, the health of employees, the chemical composition and bacterial content of the milk, and other matters having a bearing upon the wholesomeness of the milk and furnishes a dairyman, complying with the specified requirements, a statement certifying to the purity of his product.

Guaranteed milk.—The term 'guaranteed' is often applied to milk in its ordinary sense. It merely means that the producer agrees to

deliver milk of a certain composition or quality, and it should carry weight only in proportion to the reliability of the party making the guaranty.

Sanitary milk.—This is a term applied somewhat indefinitely to milk produced and handled under conditions considered necessary to secure a pure, wholesome product. It is often applied by dealers, for purposes of advertising, to milk produced under decidedly insanitary conditions. The term 'hygienic' is similarly abused.

Pasteurized milk.—This term should be applied only to milk which has been heated sufficiently to destroy most of the active organisms present. Bacteria of one kind or another are invariably present in milk obtained under ordinary conditions. Some of these cause souring of milk, while others may occasionally be disease-producing forms, such as tubercle bacillus. Milk may be heated enough to destroy all the organisms present, but when this is done it has acquired a cooked taste which is more or less undesirable. To avoid this the temperature of heating should not exceed 185° F., and at the same time to secure destruction of any considerable number of the organisms present, it must not be below 140° F. When the higher temperature mentioned is used the period of heating may be very short, but when the lower temperature is employed it must be prolonged in order to secure the same results. Pasteurization therefore merely checks fermentation. It does not destroy all of the organisms present. It should, however, destroy all disease-producing organisms likely to gain access to milk.

Sterilized milk.—This is milk in which all organisms have been destroyed. It is not always accomplished by merely boiling the milk unless the boiling is repeated on two or three successive days. Higher temperatures than the boiling point are necessary to assure sterilization or the complete destruction of all organisms at one application of heat of fifteen to thirty minutes' duration. Much of the so-called sterilized milk is by no means free of living organisms.

Clarified milk.—In passing through a centrifugal separator much of the solid impurities in milk remains in the separator slime. A mixture of the skim milk and cream so obtained is often referred to as clarified milk.

Carbonated milk.—This is milk put up in bottles and charged with carbon dioxide or carbonic-acid gas.

Homogenized milk.—This is milk in which the fat globules have been broken up by mechanical means into very fine particles, which show no tendency to rise to the surface, as do the fat globules of ordinary size. In accomplishing this purpose the milk is usually forced through capillary tubes and against a resisting surface. The force of impact causes the breaking up of the globules and thus makes a more perfect emulsion out of the milk. The process is protected by patents in various countries.

Condensed milk, Evaporated milk.—This is defined by the Secretary of Agriculture as milk from which a considerable portion of water has been evaporated and which contains not less than 28 per cent of milk solids, of which not less than 27.5 per cent is milk fat. The sweetened product contains varying percentages of added sugar.

Desiccated milk.—This product, which is usually referred to in this country as milk powder, is prepared from whole or skim milk by patented processes."

In drawing up the above definitions Dr. H. W. Lawson compiled the rulings and opinions of various sanitary officers in State and Federal service.

Milk of Mammals Other Than Cows.

In this country the milk of mammals other than cows is not much used. Milch goats, however, are gradually coming into favor, and notes on the composition of the milk of other mammals may be of interest for purposes of comparison.

Human milk.—Human milk is chalky white in color and watery in appearance. A yellowish color may be noted if the proteid content is high. It is rarely sweet, usually of an alkaline reaction. According to Richmond the average composition is water 88.04 per cent, fat 3.07, sugar 6.59, proteids 1.97 and ash .26. Great variations are observed in the constituents. Thus the fat may vary from .5 to 9 per cent, the sugar from 4 to 9, the proteids from .8 to 5.5, and the ash from .09 to .5. The proteids are not curdled by rennet, the sugar crystallizes in rhomboid plates, and the fat is low in volatile acids.

Ewe milk.—According to Fleischmann the composition of ewe's milk is, on an average, water 83 per cent, fat 5.3, sugar 4.6, casein 4.6, albumin 1.7, and ash .8 per cent. The casein is coagulated by rennet, the curd being firmer than that of cow's milk. The fat may be separated by the centrifugal or dilution methods but does not rise on standing, on account of the great viscosity of the milk.

Goat's milk.—König gives the following composition of goat's milk: water 85.71 per cent, casein 3.2, albumin 1.09, ash .76, sugar 4.46 and fat 4.78. The various constituents closely resemble those of cow's milk in character, but the fat is very white.

Reindeer.—According to Werenskiold the specific gravity of reindeer milk is 1.0477. The melting point of the fat is higher than that of cow's milk. The average composition is water 64.25 per cent, ash 1.43, fat 19.73, sugar 2.61, casein 8.69, albumin 1.66, globulin .56, amids .56, other substances .51.

Hog.—The milk is thick and strongly alkaline. The specific gravity is 1.0128. The average composition is water 84.04 per cent, proteids 7.23, ash 1.05, sugar 3.13, and fat 4.55 per cent. The fat content is sometimes as high as 12 per cent.

Mare.—The total solids seldom reach 10 per cent and the fat 1.5 per cent. The milk is always alkaline. The average composition is water 90.78 per cent, casein 1.24, albumin .07, ash .35, sugar 5.67, and fat 1.21.

Ass.—The milk of the ass was used by the ancients for bathing purposes. It is very thin. The average composition is water 89.64 per cent, casein .67, albumin 1.55, ash .51, sugar 5.99 and fat 1.64.

Mule.—The milk of the mule is white, alkaline and does not coagulate. The average composition is water 91.5 per cent, proteids 1.64, ash .38, sugar 4.8, and fat 1.59 per cent.

Camel.—The milk of the camel resembles human milk in coagulating with light flakes. It is pure white and sweet. The average composition is water 86.57 per cent, proteids 4, ash .77, sugar 5.59, and fat 3.07 per cent.

Indian buffalo.—Buffalo milk is much used in India, the Philippines, Hungary and elsewhere. The average composition is water 81.41 per cent, casein 5.85, albumin .25, ash .87, sugar 4.15, and fat 1.47.

Zebu.—This is one of the most important milk animals in India. The average composition of the milk is water 86.13 per cent, fat 4.8, casein 3.03, sugar 5.34, and ash .7 per cent.

Dog.—The average composition of dog's milk is water 75.44 per cent, casein 6.1, albumin 5.05, ash .73, sugar 3.08, and fat 9.57 per cent. The yield of milk is greater on a meat than on a vegetable diet. The reaction of the milk is always acid.

Cat.—The composition of cat milk on an exclusive meat ration is as follows: water 81.63 per cent, casein 3.12, albumin 5.96, ash .58 sugar 4.91, and fat 3.33 per ent.

Porpoise.—The milk is yellow, thick and of a fishy odor. The total solids amount to about 58 per cent. The average compositin is water 41.11 per cent, proteids 11.19, ash .57, sugar 1.33 and fat 45.8 per cent.

Rabbit.—According to Pizzi the average composition of rabbit's milk is as follows: water 69.5 per cent, fat 10.45, proteids 15.54, sugar 1.95, ash 2.5 per cent. The specific gravity is 1.0493.

Elephant.—The milk of the elephant is characterized by its high fat and low proteid content. The average composition is water 67.85 per cent, proteids 3.09, ash .65, sugar 8.84 and fat 19.57 per cent.

Partial analyses have also been made of the milk of the lama, whale, bison, catalo and other mammals but the data thus obtained are of little interest in this connection. As with cows so with other mammals the milk is influenced in its composition by such factors as breed, age, size, period of lactation, individuality, exercise, excitement, estrum, weather, seasons, food, disease, etc.

CHAPTER II.

ABNORMAL MILK.

In the foregoing chapter an account has been given of the biology, physics and chemistry of normal milk. In the present chapter it is proposed to discuss the various abnormal conditions which may be met with in milk. The abnormal features of milk may be due to striking irregularities in composition, abnormal colors due to added coloring matters or bacteria, abnormal odors or flavors due to improper feeding stuffs, absorption of disagreeable odors, to bacteria, a ropy or slimy condition, abnormalities due to conditions of the udder, ingestion of drugs or harmful plants or to the presence of pathogenic bacteria, toxins and antitoxins, to bacterial changes producing milk poisoning, to the presence of dirt or to adulterations. In the following paragraphs these abnormalities are briefly discussed in order.

Milk Abnormal in Composition.

The usual composition of normal milk as determined by the analysis of thousands of samples has been studied in chapter I. The composition of milk as discussed in that chapter may vary considerably as a result of the influence of various factors but occasionally quite striking irregularities appear in composition. For example, the fat content may be decidedly too low or too high, varying from 2 to 15%. In a case reported by Cooke the fat content was 14.6% in the milk of a cow shortly before calving. In an instance reported from Germany a cow at a similar stage of lactation, that is, when almost dry, gave milk which contained 42% of solids, of which 25% was fat. The cow was later slaughtered and found to be diseased. Milk may occasionally be watery without showing any adulteration or skimming. Such milk has a low specific gravity and is bluish in color. Sometimes a low percentage of fat is seen in milk obtained during the period of heat in cows, or as a result of improper care and feeding. It is obviously impossible to draw hard and fast lines for the minimum and maximum fat content of normal milk. In general, however, it is considered that milk containing less than 2% or more than 10% of fat is abnormal and that the conditions surrounding the case should be investigated.

Occasionally milk possesses a salty flavor due to an excess of ash content and an unusually small amount of lactose. Milk of this character is most often obtained in cases of garget. Similarly colostrum obtained during the first few days after calving possesses a high content of mineral matters and sometimes shows a decidedly

salty flavor. In rare instances milk appears to be sandy, not as a result of the addition of ordinary sand from careless handling but to the presence of small concretions of carbonate of lime which are found in the milk ducts under abnormal conditions.

Abnormal Colors Due to Added Coloring Matters and Bacteria.

Added coloring matter.—In some localities a demand is made for milk of a decidedly yellow color under the supposition that the consumer is receiving more cream than in milk which shows a bluish tinge. In order to lend this yellowish color to milk coloring matters have been added to a slight extent. In the examination of 23,000 samples of milk in Massachusetts, 151 samples contained a foreign coloring matter. The color chiefly used was annato but aniline orange and caromel had also been used in a few instancees. About 95% of the samples containing foreign coloring matter were found upon analysis to have been diluted with water. In these cases therefore the coloring matter was added in an attempt to obscure the adulteration of the milk. Saffron and more rarely other coloring matters have been added to milk for the same purpose.

As is well known a number of feeding stuffs exercise an influence upon the color of the milk. Grass, corn meal, corn silage and various succulent feeds usually have the effect of giving a rich yellow color to the milk, while dry hays, cottonseed meal and certain other feeding stuffs may have the opposite effect. Rhubarb has a tendency to produce a yellowish or in some cases a reddish tinge in milk. A brown coloration of the milk may be due to foreign substances such as filth or may be caused by the growth of certain fungi. In rare instances milk may show a greenish tinge due to a high fat content and imperfect emulsification or to the presence of fluorescent bacilli and the formation of pus in the udder.

Colors due to bacteria.—A number of well known abnormal colorations of milk are due to bacteria multiplying in it.

Blue milk was in former years reported more frequently as an abnormal condition of milk than at present. It is due to the development of *Bacillus cyanogenes.* Milk infected with this bacillus is at first not different, at least to the naked eye, from perfectly normal milk. Usually, however, it does not sour as rapidly as normal milk. After standing a short time small blue spots appear upon the surface which increase in size and gradually become confluent, covering the whole surface of the milk by the time it has soured. The blue surface coloring is in most cases complete within a few hours. In milk which contains a large percentage of fat the blue coloration does not appear so strikingly even when a bad infection with *Bacillus cyanogenes* has taken place. The blue color is at first pale, but if the milk is allowed to stand for several days the color finally becomes azure. The color

is most intense upon the upper surface but it is recognizable throughout the whole mass of milk. The coloring matter produced by this bacterial infection has been supposed by some investigators to belong to aniline dies. This supposition, however, has been thrown in doubt by other bacteriologists. The bacillus which causes blue milk may be readily destroyed by subjecting the milk to a temperature of 55 degrees C. for ten minutes. Rarely blue milk appears in epizootic form and seems to affect the product of the whole herd. In most instances, however, the infection comes from a single cow in the herd and as soon as her milk is excluded the rest of the milk appears normal

Red milk has long been known to occur with comparative infrequency. A striking red color may appear on various other food materials, particularly bread and potatoes. This coloration is due to the growth of *Bacillus prodigiosus* and may be easily distinguished from the pinkish or reddish color due to the presence of blood in milk. If any doubt is felt regarding the cause of the red color, the inoculation of a small amount of the material into any of the ordinary nutrient media will show the prompt development of a red color due to *Bacillus prodigiosus* if this organism is present. The bacillus in question does not thrive well in the presence of acid and its growth is therefore checked by the rapid development of the lactic acid bacilli. Occasionally a red coloration is produced in milk by the growth of a species of sarcina.

Yellow milk is occasionally reported as an abnormal condition. According to Adametz this is due to the growth of *Bacillus synxanthus*. A microscopic examination of yellow milk will reveal the presence of crystalline bodies, cholesterin, needle crystals, lymph cells and disintegrated fat globules. A number of bacteria have been described by Conn as producing a yellow color. Some of these organisms rapidly produce a bright coloration, while others act more like rennet, causing a coagulation of the casein followed by digestion and later by the appearance of a yellow color.

Other colors such as green, black and brown have occasionally been referred to as occurring in milk, but as stated by Conn they cannot be considered as ordinary dairy infections for the reason that they occur only in bacteriological examinations during which bacteria are grown on a sterilized milk medium. The abnormal coloration of milk due to the action of bacteria is no longer a serious matter in commercial dairying for the reason that the means for preventing it are thoroughly understood. Sunlight and cleanliness particularly in the care of dairy utensils prevent the contamination of milk with color-producing bacteria.

Abnormal Flavors and Odors.

Flavors and odors due to improper feeding stuffs.—It is a matter of common knowledge that milk readily absorbs the odors which may pre-

vail in the air of stables or milk rooms. The absorption of odors takes place more rapidly in warm than in cold milk. In a test of the absorption of the odors of volatile oils Russell found that the odor of peppermint was absorbed more readily than that of wintergreen or cinnamon. Occasionally disagreeable odors may develop in milk not as a result of absorption from various foreign substances but apparently from a contamination with bacteria, particularly *bacillus lactis foetidus*. According to Thörner this bacillus in milk may produce a putrid odor resembling that of some ammoniacal compounds.

Nearly all feeding stuffs transmit a specific flavor and odor to milk which in many instances, however, are so faint as to escape recognition except after some experience along this line. Not only the flavor and odor of feeding stuffs may be transmitted to milk but also other active principles contained in these plants. According to Tenere palm nut cake when fed in quantities not exceeding four lbs. daily gives an agreeable specific flavor to milk and the butter made from it. A number of other oily feeds such as linseed meal, peanut meal, cottonseed meal, etc., not only exercise an effect upon the firmness of butter and its color but also lend a barely perceptible flavor to it.

Distillery and brewery by-products are quite generally objected to as feeding stuffs for dairy cows for the reason that disagreeable odors and flavors are sometimes believed to be transmitted into the milk from these feeds. According to the experiments of Lindsey, in Massachusetts, however, no specific odor or flavor was given to milk as a result of feeding distillers' grains, brewers' grains or malt sprouts. Nevertheless, some milk dealers, particularly in New York City, object to the use of any of these feeding stuffs by the farmers who furnish them milk and in one or two instances even corn silage is mentioned as an undesirable feeding stuff. In a number of German experiments in which distillery residue was fed to cows the milk and butter from these cows had an objectionable potato like or alcoholic odor. Weller found that in a large herd of cows kept at a distillery the milk had an irritating after flavor and upon examination showed the presence of .9% of alcohol. These cows received no grain except distillery residue and it was soon found that the alcohol in this material could be readily driven off by the use of steam after which the slump had no bad effect upon the milk. In certain French tests of this matter no alcohol was detected in the milk of cows fed on distillery malt when small quantities of this material were fed. In general it appears that neither the flavor nor odor of alcohol appears in milk unless considerable quantities are used in feeding.

As already indicated a great many substances may be transmitted from the blood of the cow and from the feeding stuffs to the milk. Nearly all of the volatile fats and oils which are derived from fat substances may thus come to lend a specific flavor to the milk. The

flavors and odors which are most desirable come from feeding stuffs which are held in highest esteem for the production of milk, while the undesirable odors are largely due to the ingestion by cows of onions, leeks, garlic, turnips, cabbages, various kinds of wild bitter herbs and brush, fish, etc. The animal odor which appears in freshly drawn milk is objectionable to many individuals but disappears soon after the milk is drawn under the influence of aeration and cooling. This animal odor, however, is to a considerable extent due to the volatile odors which are derived from the food materials consumed by the cows. In cases where the dairyman desires to feed considerable quantities of turnips, cabbages, carrots, brewers' grains or other material which may give rise to a specific flavor or odor in milk, the matter may be easily adjusted by feeding these materials after milking rather than before. The odors then disappear and are not noticed in the milk obtained at the next milking. No satisfactory methods have been devised for removing specific odors due to plants after they once gain entrance to the milk. In the case of the odors of turnips and cabbages they usually disappear when milk is pasteurized. This is not true, however, for onions and garlic. In stables where silage is fed extensively, the odor of this material may permeate the milk unless it is removed promptly from the stable.

A bitter taste may be given to milk whenever cows eat wormwood in pastures or skunk cabbage. The disagreeable flavors which are often complained of in milk in early spring and at other seasons of the year when the pasture is poor are for the most part due to the fact that at such times the cows may accidentally eat small quantities of plants with bitter taste growing among the grass or in consequence of short pasturage may be tempted to eat various native weeds which otherwise would not be touched. This constitutes an argument of considerable force in favor of using cultivated pastures only and adopting a system of rotation which includes the use of meadows for pasture after they have been used for hay purposes for a number of years.

In New York Harding reports the occurrence of a fishy flavor in milk. The taint was so strong as to render the milk unfit for use. An investigation of this case failed to disclose a satisfactory explanation of the flavor. The dairyman in question used more than ordinary care in handling the herd and the milk. The flavor seemed to be confined to the milk of a single cow and disappeared from the herd's milk as soon as the milk of this cow was excluded. An examination of the pasture did not show the presence of any weed which might be supposed to cause the trouble.

Dombrowski carried on a number of feeding experiments with various plants and feeding stuffs to determine the extent to which the flavor of these materials was transmitted to milk. The food stuffs used in these experiments included anise seed, fennel seeds, garlic,

carrots, alizarin, etc. The odor of anise seed, fennel and garlic was readily transmitted to milk so as to give a strong flavor. The odor of garlic did not disappear after boiling the milk and allowing it to cool for 15 hours. On the other hand the flavor and odor of fennel and anise disappeared as the result of boiling the milk. The specific flavors of other plants were recognized in the milk and it appears that the volatile materials which determine the presence of flavors and odors in plants are much more easily transmitted to milk than the specific coloring matters of these plants. Alizarin, however, fennel seeds, carrots, chrysophanic acid and garlic affected the color of the milk.

Absorption of odors.—It is well known that milk readily absorbs odors which may be present in the air of stables or milk rooms. Tobacco smoke is quickly absorbed and lends a specific odor to the milk which persists for some time. It is practically impossible to obtain milk entirely free from the odor of tobacco if the dairy attendants smoke during milking and the various processes in handling milk. Many other drugs with penetrating or pungent odors are likewise absorbed by milk. In this class of substances we may mention iodoform, carbolic acid, turpentine, chloride of lime, formaldehyde, etc. Milk exposed for a few minutes in an atmosphere containing formaldehyde fumes to the extent of 1 to 100,000 showed a decided reaction of the fumes when examined by Bordas. The many observations which have been made along this line indicate that great care should be exercised to exclude disagreeable odors from the stables and milk rooms. Dombrowski also observed a rapid absorption by milk of the odors of iodoform, anise seed oil, carbolic acid, turpentine, formaldehyde and chloride of lime. The odor of iodoform persisted in the milk for twelve hours.

Abnormal flavors or odors due to bacteria.—Bitter milk has often been referred to as a specific condition due to the presence of bacteria in the milk. It is however not always due to bacteria but may be caused by rag weed, wormwood, lupines as well as various other plants, and by the prevalence of certain bacteria in the milk. In a few instances bitter milk has been observed as a result of the absorption of the odor of urine from cows showing an excessive pollution. In at least one instance bitter milk was found to be due to feeding Swedish turnips which had been washed in foul water. The milk in this case was somewhat frothy and exhibited an active process of fermentation.

Harrison investigated the cause of bitter flavors which were absorbed in milk and cheese. A yeast was isolated from samples of the curd and was also found in the milk. This yeast was *Torula amara.* The yeast was found in the milk of nearly every farm which was taken to a certain cheese factory in which the trouble occurred to the greatest extent. The use of water at a temperature of 200°F. in washing cans was not sufficient to destroy the yeast in this case.

As has been shown by Conn, a large variety of bacteria may have the effect of producing a bitter flavor in milk. As a rule the taste appears only after the milk has been allowed to stand for a considerable period of time. Bitter milk is of comparatively rare occurrence and a bitter flavor is much less often observed in milk than in cheese. Bitterness may develop slowly however in sterilized milk as a result of the growth of certain bacteria which have not been killed by heat. The bacteria which cause bitter milk may sometimes be found in the milk ducts and upon the udder of cows and are best destroyed by washing the udder with a solution of borax and injecting week solutions into the milk ducts.

Swithinbank looks upon the occurrence of bitter milk as a rather serious problem for the dairy bacteriologists for the reason that although it may occur rather rarely it is quite difficult to eradicate after it has once appeared on the dairy farm. It would seem that bitter milk may be in part due to the rapid decomposition of the casein of milk and may possibly be connected with or one of the stages of the formation of tyrotoxicon. The organisms which have been referred to as causing bitter milk include the bitter milk bacillus of Weigmann, Conn's micrococcus of bitter milk, specific bacilli described by Bleisch, Löffler, Hueppe, Freudenreich and a number of other organisms. As studied by Swithinbank, one of these species of bitter milk producers may infest a farm or dairy for months and in some cases for years before complete success is had in its eradication.

Several investigators have reported the rather infrequent occurrence of another defect of milk in which a soapy flavor may be detected. Soapy milk has been found in at least one instance to be due to an organism which occurred in considerable abundance on straw used for bedding. The milk in which this bacillus was found did not coagulate but became somewhat ropy and showed a decidedly soapy flavor. Fortunately this trouble is of rare occurrence and yields readily to the application of modern dairy hygiene.

Sour milk must be considered as an abnormal condition of milk from the standpoint of the patron of a milk route. Milk must be allowed to sour for the production of butter and, as is stated in chapter XII, milk is never free, at least under ordinary conditions, from lactic acid bacteria. When the numbers of these bacteria, however, are kept within reasonable limits, and low temperatures utilized in the handling and preservation of milk the bacteria do not multiply to a sufficient extent to cause more than the slightest increase in acidity by the time the milk is delivered to the consumer. In the case of soapy milk already referred to souring sometimes fails to take place within the usual period. On the contrary a pungent odor may develop and also a sweetish flavor. In the case of milk which has not been handled with sufficient care to keep down the numbers of lactic acid bacteria foaming may appear when the milk is run through a separator. Ac-

cording to Siedel this is mainly due to the fact that some of the casein has been dissolved by the action of the lactic acid. The foaming is more pronounced at higher temperatures.

Alcoholic fermentation may appear in milk as the result of contamination with yeasts. Certain yeasts have the power of breaking up milk sugar and producing carbonic acid gas and alcohol. The amount of alcohol produced in milk, however, is very small as compared with that which appears in the alcoholic fermentation of sugars in other products. A number of artificial beverages are made from milk by inducing alcoholic fermentation in it. The chief beverages of this sort are koumiss, kephir, matzoon and leben. These milk products will be discussed in chapter XV.

Ropy or Slimy Milk.

A large variety of bacteria have been shown to be capable of causing a ropiness or sliminess of milk and cream. These organisms have been studied by Conn, Ward, Tillman, Gruber, Marshall and many other dairy bacteriologists of Europe and this country. A sliminess in milk somewhat resembling that caused by bacteria is occasionally observed in diseases of the udder, particularly garget and in Norway it has been found that a slimy condition may be produced in milk by adding a few of the leaves of pinguicula.

Schmidt was the first to describe ropy milk in 1882 and since that time many investigations of the ropy condition of milk have been undertaken and twelve or more species of bacteria isolated as causing this condition. The temperature at which sliminess appears most rapidly after the milk has become contaminated is about that of the ordinary living room. According to Stohmann the formation of the slimy or ropy material in milk takes place at the expense of the lactose. The milk serum takes on a strongly acid reaction during the process of fermentation which produces ropiness. The ropy material may easily be obtained in the formation of a precipitate if the lactose solution or milk in which the fermentation has taken place is diluted with alcohol.

The organism which most commonly causes ropiness is *bacillus lactis viscosus.* As stated by Conn, this organism grows so rapidly that it is not greatly checked even by the presence of lactic acid bacteria. The slimy milk bacilli come for the most part from unclean water and these gain entrance to the milk vessels in the water used for washing them. This indicates a practical way of eliminating the trouble since it yields easily to the thorough cleansing of milk utensils.

In the investigations carried on by Ward at Cornell University, the *Bacilius lactis viscosus* was found to be the chief cause of slimy milk. In preventing this trouble it appeared to be most desirable to scald thoroughly all pails and other utensils as well as strainer cloths

after each using. Since as has already been stated the organism which causes slimy milk is usually present in the water, the trouble will obviously be perpetuated by continuing to use water which has not been boiled. On infected premises no water should be used in cleansing milk utensils until it has been brought to a boiling temperature so as to destroy the bacteria.

Ropy milk is objectionable more on account of its appearance than on account of any known harmful results caused by drinking it. The peculiar condition of ropiness may not appear until after the milk has been allowed to stand for twenty-four to thirty-six hours. If the milk is infected with the slimy milk bacillus the cream and milk on pouring shows long fine viscous threads. It is absolutely necessary in controlling ropiness in milk to prevent the contamination of the milk with the bacteria which cause the trouble, for these organisms will multiply sufficiently to produce ropiness even at a temperature of 45 to 50°F.

According to Tillmans milk when contaminated with the slimy milk bacillus undergoes a number of chemical as well as other changes. The solid constituents are somewhat diminished by the decomposition of lactose, the acidity is increased, the fat is slightly altered and the casein is peptonized to some extent. The organism which causes slimy milk has been in some cases isolated from straw as well as from water According to Marshall the bacteria of slimy milk may be found upon the hair of the udders and flanks of cows and possibly upon the hands of milkers. This suggests the desirability of exercising all proper precautions in sanitary milking and handling milk. Rarely cream has been observed to possess an oily and slightly gelatinous consistency while the remainder of the milk possessed normal characters. This condition is closely related to ropiness but is readily distinguishable from it, although it appears to be due to bacterial infection of the milk.

Abnormalities Due to Conditions of the Udder.

It is impossible within the limits set for this chapter to discuss all of the pathological conditions which may appear in the udder of cows and which may affect the composition or appearance of the milk. In general all infectious diseases during the course of which lesions appear in the udder result in the production of milk abnormal in one or more respects.

The udder of modern dairy breeds of cows has been developed to such a large size that it is frequently exposed to bruises of more or less serious nature. Such contusions may cause in turn the secretion of abnormal milk. If the blow or bruise be severe enough to rupture small blood vessels, blood may escape into the secreting tissue and the hemoglobin of the blood or actual blood corpuscles may escape with the milk. Following upon severe blows a swelling or edema may

occur with more or less extensive inflammation. In all such cases lymph or blood serum will appear in considerable quantities in the inflamed tissue and will escape with the milk or at any rate have the effect of changing the composition of the milk. Wherever an inflammatory condition prevails the number of white blood corpuscles soon rises far above the normal and an estimation of the leucocytes in the milk will show that they are present in too high numbers.

As a result of contusions or from other causes small blood vessels in the udder may become obstructed by the formation in them of solid plugs of the blood constituents. This condition is known as thrombosis and may lead to the disintegration of the red blood corpuscles and the secretion of red coloring matter with the milk. If the cow's udder should receive a blow of sufficient violence to lacerate the tissues, small particles of secreting cells or other tissue material might gain entrance to a blood vessel of the udder so as to stop the flow of blood when the foreign body reaches a small part of the vessel. This would lead to the condition known as embolism, although emboli are more often the result of the dislodgement of thrombi in the blood vessels and their subsequent blockade in small parts of the vessels.

The formation of thrombi and emboli are often due to the presence of ferments in the blood which cause the actual coagulation of small particles of blood into solid masses which are later caught in the capillaries or small blood vessels. Wherever these pathological conditions prevail the disintergration of the embolic material will necessarily have an influence upon the character of the milk. Small quantities of fibrin and mucuous threads may appear, together with large numbers of white blood corpuscles and epithelial cells.

In all cases of mammitis the number of white blood corpuscles in the milk is enormously increased. In all cases of contagious mammitis, pathogenic streptococci will also be found in the milk obtained from affected quarters of the udder. During the progress of mammitis or garget red blood corpuscles will escape into the milk to a greater or less extent and will give rise to bloody or pink milk. In all cases of tuberculosis and actinomycosis tubercles may be formed in the udder giving rise to swellings of various size and tissue changes, which in turn cause alterations in the character of the milk. In all cases where the udder is affected by these diseases the milk should be absolutely excluded from the market except after boiling and even after sterilization objection may be raised to it on the ground of its changed chemical composition and the possible presence of toxins or ferments which may be produced during the progress of the disease. The variations in the composition of milk due to the presence of tubercles or other disease processes in the udder are not uniform. The changes usually affect the relative proportion of the normal constituents of milk but these proportions are not always changed in the same manner. Occasionally also an increased quantity of salts and mineral matters are observed in the milk.

Tumors may affect nearly all parts of the body. The term tumor is used to denote a tissue proliferation of persistently progressive character changing the appearance and function of the affected part. During the progressive growth of tumors an excessive accumulation of tissue appears caused by cells of the surrounding tissue which appear to change their nature, become essentially parasitic and invade the tissues in which the enlargement takes place. During the growth of tumors a great variety of metabolic products and decomposition substances are set free. These substances may exercise toxic influences upon the animal in which the tumorous growth occurs and if the tumor is located in the udder the toxic properties may be transmitted to the milk. Moreover in the inflammatory area usually observed around a growing tumor the tissue is extensively infiltrated with white blood corpuscles and may also show suppurative or gangrenous growth. The white blood corpuscles, toxins and other products of gangrenous degeneration may be set free into the milk.

According to Pusch bloody milk occurs much more frequently than is generally supposed. In many instances the amount of blood which escapes into milk is scarcely sufficient to cause a red coloration which can be detected. In some instances blood appears in the milk for a short time after calving and then disappears. In two cases observed by Pusch the trouble could not be attributed to any injurious properties in feeding stuffs nor to inflammation of the udder. The cause of the presence of blood in the milk was attributed to a general state of congestion. Sometimes blood or hemoglobin appears in the milk merely as the result of a rupture of a blood vessel in the udder. In such cases the trouble may easily be remedied by the infusion of air into the udder as is practiced in treating milk fever.

Not only such diseases as affect the udder specifically may be the cause of abnormal conditions in milk, but various other general diseases may bring about changes in the composition of milk, affecting its nutritiousness or wholesomeness. Thus, in addition to those diseases which will be mentioned in chapters III and XIII, digestive disturbances as a rule cause an unfavorable effect upon the composition of milk. The milk in such cases coagulates quickly, often within six or eight hours after milking, without undergoing the normal process of souring. It has therefore an abnormal flavor, yields a cream which does not churn readily, or, in some cases, may ferment, foam or exhibit a watery, thin and bluish character. Likewise the quantity of the milk diminishes or may become almost entirely checked. In cases of jaundice the yellow coloring matters of the bile may enter into the milk so that it assumes a decidedly yellow coloration. Moreover in cases of bloody urine the red coloring matter of the blood passes over also in the milk, lending it a pink or reddish color. All serious general diseases accompanied with fever cause a diminution in the

amount of milk and also affect its quality. In some of these diseases the pathogenic bacteria are also found in the milk, as will be mentioned below. In diseases during the course of which suppuration or pyemic processes take place, the milk may become thicker than normal, somewhat slimy and in serious cases purulent. Occasionally in such diseases a greenish color is noted in the milk and a stringy or gelatinous condition. In these cases the condition may somewhat resemble that of ropy milk.

The changes usually observed in cases of catarrh or inflammation of the udder have already been mentioned. Such milk often appears rose color or red, or, more rarely, it is thin and grayish white. The milk may contain minute flakes or larger clumps of material which upon standing or after centrifugal separation may lead to the formation of a thick or grayish yellow sediment. In cases of mammary inflammation the milk is sometimes salty or at least less sweet than usual and may contain slimy flakes or stringy masses or larger coagulated clumps. In such milk an irregular coagulation may take place upon boiling. The coagulated masses are sometimes yellowish and sometimes reddish brown and taste salty. In parenchymatous inflammation of the udder the quantity of milk is greatly diminished and the color may be a dirty gray. The milk may also show irregular coagulated masses. In chronic inflammation of the udder the milk becomes watery and of a bluish color. Moreover it does not keep as well as normal milk and shows coagulated masses of varying size.

In all diseases in which pyemia or septicemia occurs, poisonous substances are formed which may pass into the milk, rendering it actually dangerous. The history of meat inspection has shown that the meat of such animals when eaten by man may cause serious cases of poisoning and it is probable that the same dangerous toxins are frequently found in the milk.

Abnormalities Due to Ingestion of Drugs and Harmful Plants.

It has already been stated and it hardly seems necessary further to urge that the milk of all seriously sick cows should be excluded from the regular milk of the herd in distributing to patrons. This is a necessary precaution on the ground that such milk may be abnormal in composition and may be actually dangerous by reason of its content of toxins or pathogenic bacteria. Moreover if such cows are treated with medicines it must always be borne in mind that such drugs may and usually do pass over into the milk, thus affecting those persons who consume it. It has already been shown that this happens in the case of strychnine, veratrin, aloes, ether, camphor, chloroform, Glauber's salts, carbolic acid, iodine, potassium iodide, borax, bismuth, lead, zinc, copper, iron, antimony, arsenic, mercury, eserin, morphine, atropin and various other drugs used as medicines in the treatment of cattle. As shown by Glage, iodine readily passes into the milk and

arsenic may be thus transmitted in such quantities as to render the milk poisonous. Mercury, tartar emetic, lead and copper, on the other hand, are not transmitted to the milk except to a very slight extent. As a rule, however, the milk of cows which have received powerful drugs as medicines should not be used. In such cases the composition of the milk ordinarily remains normal or nearly so, but the drugs may be present in a sufficient quantity to lend the milk a specific flavor and action upon the person who drinks it. For a short time after the administration of tuberculin in testing cows for tuberculosis small quantities of the tuberculin may be found in the milk but ordinarily not in sufficient quantities to render it harmful.

The transmission of alcohol to milk has already been mentioned as occurring when this substance is administered as medicine and also when it is present to a large extent in the feed, as, for example, distillery by-products. Such feeds may contain enough alcohol to affect the milk in a decided manner, not only by the presence of the alcohol but by bringing about a pronounced acid reaction in the milk. Ostertag has found that in some cases the milk of cows fed continuously upon large quantities of sugar beet pulp may contain enough potassium to render it objectonable to adults and particularly to children. Similarly wild mustard and castor oil cakes are undesirable feed stuffs on account of the fact that injurious substances are transmitted from them to the milk. In rare instances cows will eat decomposing and putrid animal or vegetable substances, including the excrement of human beings and other animals. Naturally in such cases a disagreeable odor, if no more injurious quality, is transmitted to the milk.

The list of harmful or poisonous plants which may injurously affect the milk after being eaten by cows is very large. It has been shown, for example that calves are sometimes badly affected by drinking milk from cows which have eaten feed stuffs containing large quantities of ergot. Milk sickness or trembles is a disease which has long been known as affecting cows particularly in the neighborhood of swampy or low areas throughout the central States. It has also been found in numerous instances that the milk of such cows contains the essential cause of the disease and may thus transmit the disease to calves or human beings. The cause of milk sickness is unknown although many suppositions have been made concerning it. Recently it has been asserted that the disease is due to eating white snake root (Eupatorium ageratoides). This plant was said to cause more or less serious symptoms of disease in cows which eat it but curiously enough the effect is far more serious upon those who consume the milk. The symptoms of milk sickness in man include nausea, vomiting, headache, trembling and pains in the limbs. The toxin or bacteria contained in the milk of affected cows is capable of causing the death of children and adults who consume the milk, even when the cow herself is not dangerously affected.

Likewise with larkspur, aconite, lupines of various species, death camas, wild parsnip, etc., we have observed instances in which calves and lambs at the mother's side were seriously affected and in some cases died after the mother had eaten these plants, although the mother herself was not seriously poisoned. The danger from poisonous plants is obviously greatest in those regions where cows graze on native pastures and where no attempt is made to eradicate wild species of plants. Where cultivated pastures are used such plants have little or no opportunity to thrive.

Pathogenic Bacteria in Milk.

In chapters XII and XIII descriptions are given of the pathogenic bacteria which may be found in milk and the extent of their occurrence and their agency in transmitting disease to man are discussed. All milk which contains pathogenic bacteria must be considered not only as abnormal but unfit for consumption and dangerous.

The pathogenic organisms of greatest importance in milk are those of tuberculosis, contagious mammitis, foot and mouth disease, typhoid fever, scarlet fever, diphtheria and cholera. The organisms of tuberculosis and contagious mammitis may be transmitted to the milk directly from the cow. Tubercle bacilli may also gain entrance to the milk from tuberculous attendants, in manure and in other ways. The pathogenic organism of foot and mouth disease has not been isolated but the virus is present in the milk of all cows in which the udder is affected. The virus of typhoid fever, diphtheria, scarlet fever and cholera must gain entrance to the milk after it has been drawn from the cow. All of these diseases are dangerous or fatal to man and the presence of the virus in the milk in any case is sufficient cause for excluding it from consumption.

Toxins, Antitoxins and Other Bacterial Products in Milk.

During the progress of various infectious diseases toxins, antitoxins and other products of the growth of pathogenic bacteria are formed in the body and may pass into the milk to a greater or less extent. The toxins in such cases exercise an injurious effect upon persons who consume the milk, but the antitoxins, antibodies and certain other products of bacterial growth may exercise a greater or less immunizing effect on the young sucking animal or upon human beings. This is true to some extent of nearly if not quite all diseases. The greatest interest in this connection has recently centered around the possible value of the immunizing substances in the milk of tuberculous cows. Von Behring has gone so far as to devise a plan of immunizing calves and children against tuberculosis by the use of the milk of tuberculous cows. This investigator suggests that since such milk contains the antibodies which antagonize the progress of tuberculosis it may be highly desirable to leave them in their original state in the milk in the

hope that their influence will be manifested in protecting against tuberculosis the individual who consumes the milk. In carrying out this plan Von Behring recommends that the milk of tuberculous cows should not be pasteurized or sterilized since in this process not only the tubercle bacilli are destroyed but also the immunizing substances. If such milk is treated with formaldehyde to the extent of one part in forty thousand it is claimed that the tubercle bacilli will be destroyed without thereby affecting the immunizing properties of the milk. The use of formaldehyde in milk for any purpose, however, is highly questionable and the importance of the immunizing effect of tuberculous milk in which the tubercle bacilli have been destroyed remains to be demonstrated.

Not only are the toxins and antitoxins of various diseases transmitted to the milk but also the immunizing bodies, complements, alexins, agglutinins, opsonins, reductases, etc. Reductases sometimes appear in milk as the result of bacterial contamination. Moreover according to experiments by Woodhead, the opsonic indices of milk and whey were .72 and 1.02 respectively in tuberculous cows. This investigator believes that a high opsonic index of milk is of value in protecting children against tuberculosis.

Bacterial Changes in Milk; Milk Poisoning.

The occurrence of ptomains and leucomains has been most extensively studied by Vaughan and Novy. These investigators have studied a number of cases of milk poisoning and have collected instances reported by others. In one case milk poisoning of a serious character was observed in the patrons of a milk route and gave much difficulty in the determination of its cause. The cows were well fed and cared for and the handling of the milk in most respects was quite satisfactory. It was observed, however, that the milk delivered at night was highly injurious while that delivered in the morning caused no bad effects. Upon investigation it appeared that the dairyman was in the habit of milking the cows at noon and at midnight. The milk obtained at noon was placed in cans while still warm and thereupon, without any refrigeration, was hauled a distance of about eight miles during the warmest part of the day. The milk thereby became somewhat unpalatable and also developed highly dangerous ptomains which caused milk poisoning in the patrons of the milk route.

In some of the individuals who suffered from milk poisoning the body temperature was as low as 94 degrees F. and in most instances was subnormal. At least one family was affected with a uniform set of symptoms in every case and all cases proved fatal.

In another case of milk poisoning reported by Vaughan and Novy, the ptomain identified as tyrotoxicon developed in milk which was kept in one corner of the living rooms that had been transformed into a buttery. The woodwork of this room was moist and some of the

boards had rotted away, necessitating the placing of a second layer of boards over the original floor. A large mass of moist decomposing matter had accumulated between the two floors and emitted a peculiar nauseating odor. The milk which was kept in this place soon developed tyrotoxicon and proved to be highly poisonous to all who consumed it. Kinnicutt succeeded in isolating tyrotoxicon from milk which had been kept in an unclean vessel. It appears therefore that this substance may develop under a variety of conditions.

According to Vaughan and Novy tyrotoxicon may be obtained from filtered milk by neutralizing it with bicarbonate of soda and extracting with ether.

Blythe has isolated from milk two alkaloidal substances which are considered to be leucomains and which are called galactin and lactochrome. No experiments have been made with these substances to determine their pathological effects.

Milk Obtained During the Period of Heat.

In studying the various factors which may influence the quality of milk, Doane has considered it of importance to note the effect of heat or estrum and has collected the results reported by the investigations of others. In some cases during the period of heat the fat content has dropped as low as .7% and the milk curdled on being heated to the boiling point owing to the presence of an abnormal quantity of albumin. In another instance the content of protein and the acidity were found to be higher than in normal milk, while in still another case the milk obtained during the period of heat proved to be unfit for manufacturing into cheese.

During Doane's observations it appears that the milk showed an increase in fat content to the extent of one per cent during the second and third days of heat and that there was practically no variation in the other solids. In some cows no appreciable variation was exhibited in any of the milk constituents and none of the cows showed an abnormally low fat content. Doane concluded from his observations, therefore, that at least so far as chemical anaylsis is concerned milk from cows during the period of heat is in a practically normal condition and suitable for consumption. Fascetti observed a slight increase in the percentages of fats, proteids and total solids in milk during estrum.

Leucocytes in Milk.

Many investigators have considered the presence of leucocytes in milk as an important matter in the determination of its fitness for use. Various attempts have been made to set up a normal standard for the leucocyte content of milk, but according to recent observations these attempts have not given very satisfactory results It has generally been assumed that a direct connection exists between the presence of leucocytes in milk and pathogenic streptococci such as may cause contagious mammitis or other suppurative processes.

Eastes made an examination of 186 samples of milk from various parts of England with particular reference to a determination of the character of cells present in the milk as well as pathogenic micro-organisms. This investigator found, as have all others who studied this subject, that normal milk always contains leucocytes. During the first days of lactation colostrum corpuscles are present as well as leucocytes and the attempt has also been made to distinguish between leucocytes and pus cells. The distinguishing characteristics which have been set up as existing between these two kinds of cells, however, appear to be of little value in the light of recent investigations. Eastes found that the leucocytes are frequently associated with mucous threads and that the latter are nearly always accompanied by pus cells. Eastes came to the conclusion that mucous threads may usually be considered as corroborative proof that the leucocytosis in such cases is due to some inflammatory lesion. The presence of an excess of leucocytes and mucous threads was held to constitute muco-pus and to indicate lesions in the udder. In cases where the leucocytes were not accompanied by mucous threads, leucocytosis seemed to be connected with the presence of streptococci which appeared in nearly every sample of milk which contained pus and were rarely found in milk not thus polluted. Eastes believes that unboiled milk containing these streptococci is responsible for some of the cases of infantile diarrhea and mortality.

One of the most elaborate investigations of leucocytes in milk was carried out by Doane at the Maryland Agricultural Experiment Station. In the attempt to define normal milk and to characterize the different variations in composition and condition which may constitute abnormal milk it was considered desirable to study the occurrence of leucocytes and if possible to determine the number which may be taken as a standard for normal milk and in general the conditions under which leucocytes appear to an abnormal extent. Whenever the milk of cows becomes stringy and contains hard lumps it is taken for granted that an inflammation is present in the udder. This condition of the milk may readily be noted by the milker and an investigation of the cause of the trouble should at once be made. In the meantime the milk should not be used for human food. A number of investigators, as already indicated, have studied the occurrence of leucocytes in milk but no unanimity of opinion has been reached regarding their importance in distinguishing between normal and abnormal milk. Doane working in co-operation with Buckley soon felt the need of a more accurate method of determining the number of leucocytes in samples of milk. For this purpose the most satisfactory instrument was found to be the blood counter used by physicians and veterinarians in diagnosing diseases in which the number of blood corpuscles is affected. The glass tube of the hemacytometer contains one ten-thousandth part of a cubic centimeter and may be

examined under the microscope with an objective sufficiently strong to permit the ready identification and counting of leucocytes. According to the Doane-Buckley method 10 c. c. of milk are centrifuged for four minutes at a speed of 4,000 revolutions per minute. The fat is then removed with a cotton swab and the skim milk centrifuged again for one minute or more and the cream again removed. The reason for the removal of the fat is that the fat globules if present in the milk form a layer on the surface and interfere with the counting of the leucocytes. After centrifuging the milk a sediment will be found at the bottom of the tube amounting to as much as one c. c. in cows badly affected with garget. The milk above the sediment is removed with a small syphon using care to keep the point of the syphon near the surface of the milk so as not to agitate it. Two drops of a diluted alcoholic solution of methylene blue are then added and thoroughly mixed with the sediment, after which the mixture is boiled for a few minutes for the purpose of intensifying the coloration of the leucocytes. Water is then added to the mixture to make the color of the liquid as a whole less intense. Some care must be exercised in transferring a drop of this stained liquid to the blood counter. After the glass tube of the counter is filled it is covered with a cover glass and the leucocytes are allowed to settled to the bottom. In ordinary samples of milk the polynuclear leucocytes are present in largest numbers together with a few small leucocytes with large nuclei. With a blood counter holding one ten-thousandth of a c.c. the amount of material added after treatment, according to the method just described, will be a proportion of the original 10 c.c. of the milk sample such that if the number of leucocytes found in the sample be multiplied by 1000 the resulting number will be the total number of leucocytes per c.c. of milk. Each square m.m. of the counting chamber is ruled off into 400 smaller squares of equal size to facilitate the accuracy and rapidity of the count.

This method of determining the number of leucocytes is a simple one and has proved perhaps the most satisfactory and reliable of all those which have been proposed. In careful comparative tests with other methods it has given more satisfactory results in nearly all cases.

In the opinion of Doane leucocytes are an indication of an inflamed condition of the udder, particularly if their number is large. Milk containing excessive numbers of leucocytes will therefore have to be considered as unfit for use, particularly in the case of infants. The ease with which leucocytes may escape from the blood or lymph into the milk has generally been recognized by dairy bacteriologists. In fact the udder is not the only gland into which leucocytes penetrate from the blood. Various other glandular structures and also the urine commonly contained leucocytes. Doane maintains, however, that whenever there is an evident inflammation of the udder with evidence

of thick milk or hardening of one or more of the quarters there is always an abnormally large number of leucocytes. In all pus there is a large number of leucocytes and in fact pus cells and leucocytes are closely related if not identical structures.

After it is admitted that a considerable variation is noted in the number of leucocytes present in milk, we still have the difficult matter of deciding the exact line of demarcation between normal and abnormal milk in so far as the number of leucocytes is concerned. In many of the samples of milk examined by Doane and Buckley, mucous threads and fibrin were found as an evidence of inflammatory conditions of the udder. An effort was made to distinguish, if possible, between the leucocytes found in the milk as the result of inflammation and those which occurred in the blood of the same cow. The fibrin in bad cases of garget was apparent in the form of masses of threads which did not absorb the colors used for staining the leucocytes. It was found possible, however, to stain the fibrin threads by means of carbol fuchsin. Fibrin was not always present in Doane's examinations in the samples of milk which contained a high leucocyte count. The fibrin appeared to cling closely to the glass of the counter tube and rendered it difficult to count the leucocytes. It was found possible, however, to absorb the fluid and the leucocytes by means of filter paper inserted at the bottom of the tube, while the fibrin for the most part remained at the top. This gave a means of separating the fibrin and readily identifying it. In staining the fibrin the best results were obtained from the use of Delafeld's hematoxylin to which 15% of carbolic acid had been added. With this stain the fibrin threads took on a dark blue or purple color within ten minutes. In applying this method for the identification of fibrin and the estimation of the number of leucocytes a number of observations were made on a cow with one hard quarter in the udder. At first the number of leucocytes per c.c. was found to be 15,000,000 to 20,000,000 and some fibrin was present. After the leucocyte count had fallen to 520,000 per c.c. the fibrin was found to have disappeared. In most cases fibrin was not to be demonstrated in the milk unless the leuco cyte count rose to 1,000,000 per c.c. Doane concludes therefore that the presence of 500,000 leucocytes per c.c. renders the milk suspicious and 1,000,000 per c.c. indicates an undoubted inflammation of the udder.

Savage made a number of leucocyte counts in milk according to different methods including that of Doane. In examining these samples of milk streptococci were frequently found. in fact these organisms were demonstrated in 42% of the samples of milk. Since in these cases all of the cows were healthy the results are considered as showing clearly that streptococci as a class are very prevalent in milk. Leucocytes were present in every sample ranging in numbers from 35 to 4380 per cubic m.m. in the milk from individual cows and

from 21 to 1980 in mixed milk. Savage's results indicate no connection between the number of pus cells and streptococci. He states that he cannot differentiate between a leucocyte and a pus cell and is not prepared to establish an arbitrary standard as to what number of leucocytes in milk shall be held as indicating the presence of pus.

In a study of leucocytes in milk by Russell, these cells were found to the extent of more than 1,000,000 per c.c. in 3% of cows and more than 500,000 per c.c. in 10% of cows. The high numbers were frequently found in milk from perfectly healthy cows. It is considered by this investigator, therefore, that the matter needs more study before an arbitrary leucocyte standard is possible. Similarly Harris has found it impossible to lay down hard and fast rules regarding the importance of leucocytes. Harris believes that pus cells and leucocytes are identical structures. In his opinion leucocytes in milk up to a certain number are physiological but beyond that pathological. The line between these two conditions is an arbitrary one. It is suggested therefore that leucocytosis needs more study. Perhaps the significance of the pus cell in milk has been overrated. At any rate a veterinary inspection of the udders and less dependence on a mere examination of the milk for leucocytes will give more reliable results. According to a recent study by Ward we are not yet in a position to establish a leucocyte standard for milk.

Dirt in Milk.

In the process of milking and the subsequent handling of milk opportunity is offered for dust, manure, sand and other kinds of filth to fall into the milk. The amount of such foreign material contained in milk will obviously vary according to the carefulness with which the milk is drawn and handled. Under the most satisfactory conditions a certain amount of dirt gains entrance to the milk and when no special effort is made to keep the cows clean or to exclude dirt from the milk the amount of filth which gets into the milk is sufficient in some cases to render it disgusting. Some of the determinations which have been made by different investigators of the amount of dirt in milk have been collected by Kober. Every milk consumer has observed the presence of milk sediments which appear after the milk has been allowed to stand. This occurrence is so common that it is sometimes considered one of the natural features of milk. It has frequently been pointed out, however, that these milk sediments are largely made up of the manure of cows and other almost equally filthy and disgusting substances. Determinations of the amounts of filth in milk in various cities in Germany indicate that the quantity varies from 3.8 m.g. to 12 m.g per liter. In some samples of milk collected in the City of Washington and studied for the purpose of determining the amount of filth present, as much as 180 m.g. were found per quart of milk.

All materials which are commonly grouped together under the head

of dirt in milk must be considered as abnormal additions to the milk. The manure and dust from stables invariably carry large numbers of bacteria which cause not only active fermentation in the milk but produce disagreeable flavors and in some cases dangerous products. Various filter methods have been devised for the determination of the amount of dirt in milk, but these methods need not be described in detail in this connection. For the most part these methods involved running the milk through a centrifugal apparatus so as to throw the sediment in the bottom of the tube, after which the sediment is collected upon an asbestos filter, dried, and the total amount present in the milk is estimated from the dry weight of the filth thus collected. In a comparison of the amount of dirt present in cream, new milk, gravity skim milk and centrifugal skim milk, in Norway, it was found that the amount of filth per liter averaged 1.5 m.g. in cream, 2.6 m.g. in new milk, 2.1 m.g. in gravity skim milk and .3 m.g. in centrifugal skim milk.

Adulteration of Milk.

The usual methods of adulterating milk consist in the partial removal of the cream and the addition of water, together with the use of various foreign substances for preventing the detection of the bluish color which would thus appear in milk, or various drugs for the prevention of fermentation in milk, or for the neutralization of the acidity after souring has actually begun. The adulterants which have actually been used in milk include water, aniline dies, annatto, soda, borax, boric acid, salicycil acid, formaldehyde, flour, arrowroot, farina, chalk, gypsum, tragacanth, magnesium carbonate, caramel, decoctions of bran, barley, rice, etc.

The addition of water for the removal of cream lowers the nutritive value of the milk. If the cream is removed with care the milk may not thereby become contaminated. If water is added to the milk, however, contamination is likely to occur unless the water is absolutely pure. Moreover an individual who would deliberately water the milk intended for his customers would probably not suffer any compunctions of conscience regarding the quality of the water which he uses for adulterating his milk. A number of instances have been reported in which typhoid fever was caused by adulterating milk with contaminated water. The matter of the use of preservatives in milk will be discussed in chapter X. On account of the fact that milk is obtained twice daily there is little excuse for the use of any preservatives in it. Even where the milk must be shipped 300 to 400 miles to cities the application of refrigeration renders the use of preservatives quite unnecessary and inexcusable. The addition of coloring matters to milk is equally unnecessary. The whole milk of healthy cows fed on suitable rations such as the up-to-date dairyman should know possesses a satisfactory color without any manipulation.

CHAPTER III.

HYGIENE AND DISEASES OF COWS.

The great importance of giving careful attention to the health of cows should be obvious to all dairymen. Cows are kept for milk production for 10 to 12 years or even longer, while beef cattle are marketed at the age of 1½ to 3 years. The liability to disease is, therefore, much greater in the case of dairy cows on account of their long life if for no other reason. Moreover, milch cows are usually kept closely confined and are thereby subjected to many artificial conditions which may become a source of danger if reasonable sanitary requirements are not complied with. It should also be remembered that the period of lactation has been extended so as to be almost continuous from one calving to another and the milk yield has been greatly increased by breeding and selection with these definite objects in view. This large production of milk for so long a period puts severe demands upon the vital energies of the cow.

In order to meet these great demands it is necessary to give attention to all details of care and management which may in any way affect the health of the animals, for any diseased condition in the cow may not only endanger the life of the animal and the health of the consumers of the milk but also leads to a diminution in the milk yield.

Exercise.

Attention may be properly called, in the first place, to the influence of exercise upon the health of cows. During the summer months nearly all dairy cows have more freedom than in winter and for the most part the exercise thus secured is quite sufficient for the preservation of their health in a vigorous condition. In winter, however, it is necessary to house the cattle more closely and the problem of securing exercise under proper sanitary conditions is somewhat more difficult. Nearly all practical dairymen and veterinarians are agreed that a certain amount of exercise is necessary for reasons of health. The exact amount required will naturally vary somewhat according to the conditions which prevail about the premises. Exercise should not be given under conditions in which the animals are unduly exposed to storms or the inclemency of the winter weather. For milch cows it is probably best to be given in the form of the freedom of covered sheds or dry yards in which the animals have access to sheds. Advantage may and should be taken of this period of exercise to clean out the stalls in which the cattle are confined during the rest of the day, in order to keep them in a sanitary condition.

Grooming.

Considerable importance attaches to the grooming of all animals and perhaps especially of dairy cows. The maintenance of the skin in a clean and healthy condition is not only desirable in order to avoid contamination of milk with filth and bacteria during the process of milking but also on account of the direct relation between a healthy condition of the skin and the active performance of digestive functions as well as a general feeling of bodily comfort. It has been shown by experiment that the process of digestion may be stimulated by cleansing and rubbing the skin. A further advantage of still greater importance consists in the fact that when the skin of cattle is properly cleaned and groomed it reacts more promptly to temperature changes and thus more effectively protects the animal against various forms of congestion and inflammation due to colds. The methods of grooming need hardly be discussed. By the vigorous use of brushes and combs, which may be obtained anywhere of dealers in such articles, or even by the use of wisps of hay or straw, the greater part of the loose dust and filth may be removed. In some instances, it may be necessary to use soap and warm water to remove filth which adheres to the skin more firmly.

Regularity in Care.

Perhaps in the case of no domestic animal is the importance of regularity and care in feeding greater than in the milch cow. It is not only necessary that the rations should be of proper size and fed at suitable intervals but that the materials composing the rations should be chosen so as to constitute a balanced ration. Materials to be chosen for this purpose will, of course, vary considerably according to the locality and only a few general suggestions can be properly made in this connection. The most successful rations, both from a standpoint of milk production and of the preservation of milk, include suitable quantities of roots, silage, soiling crops, or pasturage in addition to hay and grain. Silage may be fed in rations of 40 to 60 lbs. per day with the addition of 8 to 10 lbs. of hay, and grain rations of 2 to 12 lbs. depending upon the character of the grain and the individuality of the cows but usually in rations not to exceed 8 lbs.

Feeding.

The quality of all of these food materials should be the best. Moldy hay and rusty or smutty straw may not only be a source of contamination to the milk but also produce occasionally more or less serious diseases including various forms of digestive disturbances and pneumonia. Under certain conditions, for reasons which are not well understood, smutty corn or grain may be fed in large quantities without producing any harmful results. It is never desirable, however, to take chances with such forage since at times serious losses are en-

countered from this cause. In one instance in Montana, one-half of a large dairy herd died within a few hours after being fed on smutty oat-hay. Similar statements may be made concerning moldy or smutty grain. Not only may such material cause acute indigestion with bloating and death in some cases but the lungs of the cattle may be affected by the germination of the spores inhaled from such material, and disagreeable odors may be communicated to the milk.

The question of the times for feeding and the intervals between feeding periods may best be left to the individual dairymen to be settled according to the exigencies of each case. It has been shown, however, that regularity in the time of feeding is of great importance not only in its influence upon the milk yield but upon the contentedness and consequently upon the health of the cattle. Since dairy cattle are of comparatively nervous disposition, it is obviously desirable that all precautions be taken to prevent any unnecessary worry or excitement on their part. It is good practice, therefore, to feed the cattle at, as nearly as possible, precisely the same time each day in order that the cows may learn when to expect their rations.

One of the most important factors in the successful feeding of dairy cows is to maintain the appetite and digestion in an unimpaired condition. For this purpose it is necessary to make suitable changes from time to time in which attention should be given to substitutions such as will satisfy the requirements of a properly balanced ration and prevent sudden changes in the character of the ration as a whole. Sudden changes in the ration are easily avoided in summer and in winter. The most striking alteration in the character of the ration takes place in the spring and fall when the change occurs from the stable feeding to pasture or *vice versa*. At these times it is desirable to make the change as gradual as possible by feeding a little hay along with the pasture grasses or other succulent food.

Bedding.

Since the maintenance of the proper sanitary condition of stables requires that the floors be made of hard impervious material, it is necessary to furnish the cows with a suitable litter or bedding both for warmth and comfort. Even the bedding should be selected with reference to suitability for such purposes. It should not consist of dusty, filthy material or of rusty or smutty straw. The same arguments are in force against the use of such material for bedding as in the case of feeds. The dust arising from smutty or filthy bedding may contaminate milk and may be a source of danger in the production of lung diseases. Suitable bedding material may be found in clean straw of cereals or in sawdust, shavings, and similar materials.

Water.

The water may become a factor in the production of disease in animals by reason of the impurities which it may carry or when used

either in deficient or excessive quantities. Impure or contaminated water may contain low forms of vegetable and animal life including algæ, fungi, bacteria, and protozoa and other animal species. All of these organisms of animal and vegetable nature may be present in either a living or dead condition. Various animal and vegetable substances may be carried by water in the form of sewage or other filth. Water naturally holds in solution a considerable variety of mineral salts which add to its nutritive value and palatability. Under certain conditions harmful mineral substances may be carried in the drinking water.

A deficient amount of water may diminish the amount of the excretion from the skin and the kidneys and may cause impactions in the digestive canal of cattle. A considerable quantity of water is absolutely necessary for the proper performance of the functions of the kidneys and the digestive organs. Water in moderate quantities has been found in recent experiments to stimulate slightly the formation of the digestive juices and may thus actually aid, to a certain extent, the ordinary process of digestion. An excessive amount, however, may diminish the digestibility of feeding stuffs and thus lead to an increase in tissue waste and to certain forms of indigestion.

The health of cows may best be preserved in so far as the water is concerned by furnishing an abundant supply of fresh, pure water always accessible to the cows. Cows may be expected to drink from 40 to 100 lbs. of water per day according to the ration consumed. The effect of varying quantities of water upon the bodily comfort of cows is indicated by the fact that more milk is given and the cows appear less uneasy when allowed to drink at will than when watered only at intervals of considerable length. Wherever a constant supply of water is maintained, however, particular attention must be given to preventing its contamination with bacteria and various kinds of dust and other filth. The supply of water for drinking purposes on farms is very different on different farms. . In some instances, water is obtained from running streams, while in others it comes from springs, cisterns, or wells. The relation of water to animal disease is, perhaps, more intimate than is usually supposed. Recently much attention has been devoted to the protection of the water supply of cities but as a rule efforts in this direction have been confined to the purification of water for human use. At the same time the opinion prevails too widely that water may be quite unfit for human use and still good enough for animals. An examination of water from different sources at the Indiana Experiment Station showed that its content of bacteria may vary enormously. The number of bacteria per cubic centimeter varied from 4 in tubular wells 60 to 150 ft. deep to 2,680,000 in a hog wallow. The water obtained from clean stock troughs, tile drains, and cisterns was comparatively free from bacteria. The same may be said for river water except in the immediate vicinity of cities.

Wells which receive surface drainage were found to contain very impure water and the same condition was observed in stock troughs not properly cared for. The soil acts as an effective filter upon bacteria which may come in contact with it. Experiments have shown that only a small per cent of bacteria pass through the first inch of soil, while nearly all of the disease producing bacteria are destroyed by filtering through a few feet of soil. In examinations of different strata of soil by the Indiana Experiment Station it was found that the number of bacteria varies from 2,800 at a depth of 54 in. to 518,400 at the surface. The number of bacteria 1 in. underneath the surface is found to be 51,200 under similar conditions. This shows the effective filtering action of the soil and indicates that the great majority of bacteria are contained in the first inch of the soil. The relative proportions of bacteria at different depths were quite similar before and after rain storms, being somewhat greater, however, after showers. As a rule, the bacteria found in water are not injurious and do not cause specific diseases. Whenever bacteria are present in large numbers, however, this fact may be taken as an indication of the presence of considerable organic material in the water and consequently of its unwholesomeness. Water may readily carry the bacterial organisms of blackleg, anthrax, and certain other diseases which affect cattle, as well as typhoid and other human diseases.

The protection of the water supply on farms is ordinarily a simple matter. It is necessary to prevent the undue contamination of the water with the feces of animals and it is also obviously desirable that hogs and other animals should not be allowed to stand in the water supply which may be used for cows or other domestic animals. In addition to bacterial diseases, liver flukes, which cause serious infestations in calves, and lung and stomach worms are largely conveyed by an impure water supply and the vegetation growing along the border of contaminated pools or streams.

It is evident from this discussion that the water supply is as important in the sanitation of domestic animals as in the preservation of human health. Water should not only look clear but should not possess disagreeable odor or flavor. Wherever any contamination is suspected it is a comparatively simple matter to make tests for the determination of certain substances which indicate the presence of contamination. In order to determine whether nitrites are present it is merely necessary to take 50 cc. of water and add 1 cc. each of dilute hydrochloric acid, potassium iodid solution, and a starch solution. The development of a blue color indicates the presence of nitrites. If no blue color develops within 2 minutes it may be assumed that no nitrites are present. In testing for nitrates take 50 cc. of the water to be examined and add 1 cc. of dilute sulphuric acid (1 part in four), 1 cc. of starch solution, and a minute crystal of potassium

iodid. If no nitrites appear to be present add a few milligrams of zinc dust previously mixed in distilled water. A blue color will appear if nitrates are present. A simple test for ammonia in water may be made as follows: Take 50 cc. of the water to be examined and add to it 2 cc. of a concentrated ammonia-free soda solution. After the precipitate has settled the clear fluid above is treated with 1 to 2 cc. of Nessler's reagent. A yellowish coloration or a yellowish-red precipitate (mercuric ammonium iodid) indicates the presence of ammonia. Lead in water may be detected by adding acetic acid and hydrogen sulphid. In the presence of sulphur a black precipitate is formed which may be redissolved in nitric acid, then the addition of a dilute solution of sulphuric acid produces a white precipitate which turns black when hydrogen sulphid is added. In testing water for copper the sample may be rendered slightly acid by the addition of acetic acid after which hydrogen sulphid produces a black precipitate. If this precipitate is dissolved in nitric acid and the diluted solution then treated with ferrocyanid of potash gives a brownish-red precipitate of ferrocyanid of copper.

The bacteriological methods used in the examination of milk are also applicable for the examination of water which is suspected of being contaminated with pathogenic organisms. These methods are described in another place. It is perhaps even of greater importance that scrupulous care should be exercised in the protection of the water supply than in case of food supply since bacterial infection may be carried in the drinking water to the cows and in the water used for washing purposes to the milk cans and other utensils. The bacterial contamination of water is almost certain to take place sooner or later in unprotected wells which are located too close to stables or other sources of filth so as to receive surface drainage. The importance of the protection of the water supply becomes more apparent when attention is called to the considerable length of time during which pathogenic bacteria may live in water. To be sure, most disease-producing bacteria gradually lose their virulence in water under the influence of dilution and the action of harmless bacteria. According to Boucher the typhoid bacillus retains its virulence in water not longer than 48 hours. Experiments carried out by Kasparek, however, show that the bacilli of hemorrhagic septicemia of cattle may live in water for 31 days, the virus of foot-and-mouth disease for 19 days, anthrax spores for 1½ years, anthrax bacilli for 8 days, tubercle bacilli for 5½ months, tetanus bacilli for 15 months, rabies virus for 17 days, and cowpox virus for 5 months. It has also been shown by experiment that the tetanus bacilli may remain virulent in dry pus and other animal material for 16 months. In dry sputum and tuberculous pus the tubercle bacilli remain alive but not very virulent for about 7 months even under the influence of diffuse sun light. Anthrax bacilli retain their virulence in dried blood for about 2 months, in an

almost isolated condition at a temperature of 16 to 22°C. in sun light for 18 days and under similar conditions at a temperature of 33°C. for 12 days. Blackleg bacilli have been shown to retain their virulence in dead muscle for 6 months. These data are presented in this connection on account of their importance in the possible transmission of infectious diseases through the medium of water. It is obvious that animal carcasses or parts of dead bodies containing pathogenic bacteria may be left in exposed situations for months and may be washed away in water and become distintegrated so that the disease-producing bacteria gain entrance to the water supply for domestic animals. The only way to protect the water supply successfully, therefore, is to observe scrupulously all the requirements of cleanliness and sanitation.

Salt.

Cows require a certain amount of salt in order to remain in health and in order that the physiological processes of digestion and milk secretion may actively continue. The effects of the deprivation of salt are usually referred to under the term salt hunger and may become quite serious if salt is withheld for long periods. Some of the most striking instances of salt hunger are observable in the arid regions of the western States where cattle are forced to eat alkali on account of not being supplied with salt. The common forms of alkali are carbonate of soda and sulphate of soda and can not be supposed to replace salt in the physiology of animals.

Disinfection.

By the strict observance of all precautionary measures outbreaks of infectious diseases among cattle may be reduced to a minimum. Such outbreaks, however, can not be entirely prevented and this fact makes it necessary to discuss a general plan of disinfection for the purpose of checking the spread of infectious diseases after an outbreak has occurred. The problem of disinfection after the occurrence of animal diseases is a much more difficult one than in the case of disinfection of human dwellings. In the first place, stables are usually not built of materials which lend themselves so readily to disinfection, they are constructed more loosely and this fact largely prevents the effective use of gaseous substances for destroying bacteria.

After the occurrence of an infectious disease it is necessary to disinfect all utensils, instruments, equipment, or materials of any kind which have come in immediate contact with the diseased cows. All bedding, rubbish and filth in the stables should be removed and burned. Mangers should be thoroughly cleaned and washed by scrubbing with an antiseptic solution such as 4 per cent of formalin, 5 per cent carbolic acid, or 5 per cent lysol. Corrosive sublimate, 1 part to 1,000 in water may be used on wood work and all other material except

metals. Small instruments and other articles which lend themselves readily to such treatment may be boiled. Creolin at the rate of 1 part to 50 parts of water may be substituted for any of the disinfectants just mentioned. In all disinfectant operations it should be remembered that direct sun light is one of the best natural agents in the destruction of bacteria and special efforts should be made to secure its thorough admission to all possible parts of the stable together with good ventilation. No contaminated material or carcasses of animals dead of infectious diseases should be buried shallow in the ground or be placed so that drainage may occur from this material into the water supply. It should be remembered that dogs, cats, crows, turkey buzzards, and other animals may feed upon such material and thus serve to spread infection to an uncontrollable extent.

In the vicinity of large abattoirs or wherever digesters have been established for the utilization of animal carcasses it is possible to obtain some return for such material. By means of digesters and similar apparatus animal carcasses are rendered absolutely harmless and at the same time fat, gelatin, and fertilizers are obtained from the material. In country districts the best methods of disposing of animal carcasses are burying to a depth of from 4 to 6 feet or burning. If carcasses are to be buried they should be covered with quick lime or sprinkled with chlorid of lime. Burying is perhaps necessary in many localities where the supply of fuel is scanty or where burning would be an expensive process. Extensive experience was recently had along this line by the Bureau of Animal Industry in the eradication of foot-and-mouth disease among dairy cows and other cattle. In the work of the Bureau both burying and burning were employed in destroying carcasses of diseased cattle. The cost of burning dead animals and the applicability of the method was recently studied by McDowell of the Nevada Experiment Station. It was found possible to destroy animal carcasses at a reasonable expense by the use of sage brush, refuse wood, or brush trimmed from trees with the addition of kerosene oil to hasten or complete the destruction of the carcass. The amount of oil required varied from 2¾ to 5 gal. and the total expense for material and hire of a man varied from $1.56 to $5.87 per animal. It is probable that the cost of the operation could be considerably reduced by the establishment of neighborhood organizations for this purpose. Pieces of railroad rails or other similar iron bars may be conveniently placed for supporting the animal carcass and a trench may be dug underneath the iron bars in which crude oil or other materials may be burned for incinerating the carcass. In removing animal carcasses for burying or burning no chances should be taken of spreading the disease by dragging the animal on the ground. It is better to construct a cheap "mud boat" on which the animal may be hauled and which may be burned together with the carcass. It scarcely needs mention that cows dead of dangerous infectious diseases such as anthrax and foot-and-mouth disease should not be skinned.

After a preliminary cleaning of stables there are several methods from which a choice may be made for bringing about complete disinfection. All exposed parts of the stable may be covered with a thick white wash or with milk of chlorid of lime. A 4-per cent solution of formalin may be added to the white wash to increase its effectiveness. One objection to the use of chlorid of lime consists in the fact that the odor of this substance may be perceptible in the milk long after its application to the walls and ceiling of the stables. Whatever antiseptic is used it should be applied thoroughly to the mangers, floors, stalls, ceiling, and walls so as to thoroughly disinfect all parts exposed to the contagious material. In some instances it may be convenient to use boiling water or direct live steam in disinfecting the stables. If these methods are adopted care should be taken to be sure that the water is at a boiling temperature when it comes in contact with the surfaces to be disinfected, otherwise pathogenic bacteria will not be destroyed. These methods are under the best conditions less effective than the use of chemical disinfectants. Carbolic acid in a 5-per cent solution is reasonably certain to destroy all sources of contagion but is open to the objection that it may taint the milk with its disagreeable odor. Cresol in 5-per cent solution in water has also given excellent results in disinfecting stables. Direct dry heat may be applied to walls by means of a blast lamp such as is used by plumbers. By means of this apparatus a sufficient temperature may be quickly produced on the surface of walls and stalls to destroy any bacteria which may be present.

Formalin in a 4 or 5-per cent solution in water is one of the most efficient disinfectants for use in stables. It may be used on all materials including metals and does not cause corrosion. It is volatile and, therefore, the odor remains about the stable for only a short time. During the application of formalin either in a fluid or gaseous form, the fumes cause considerable irritation in the eyes and respiratory passages of the workmen. Formaldehyde fumes are less applicable for use in stables than human dwellings. The fumes do not penetrate very rapidly and it is quite necessary that the stable be rendered as nearly air-tight as possible in order that the fumes may have their effect. This, however, is practically impossible in most stables since the quarters in which the cows are confined usually communicate with the hay mows and other parts of the barn. Where the contaminated part of the stable can be tightly closed, however, formalin brings about a rapid disinfection of all exposed surfaces. As already indicated, however, it is necessary that straw and filth be removed and cracks be filled up in order to allow the formalin fumes to come directly in contact with all bacteria. In the application of formalin or other chemical disinfectants it should be remembered that the action of these substances is more effective when a moderately high temperature is maintained in the stables. One of the great advantages of formalin consists in the fact that it is a true deodorant. It does not con-

ceal one odor by emitting another but unites with the albuminous matter in feces and other materials about the stable to form new chemical compounds which are odorless and sterile.

Potassium permangenate is a disinfectant of great power but its application is quite limited on account of the fact that it is readily rendered inert by coming in contact with organic material. Its chief use is in the purification of water. Wells or cisterns which are believed to have become contaminated with pathogenic bacteria may be disinfected by the use of merely a sufficient quantity of permangenate to give a slight tinge of color to the water. Cows appear not to be harmed by drinking water containing minute quantities of potassium permanganate although no data are available regarding the possible cumulative effects of this substance.

White wash or milk of lime is one of the commonest and most convenient disinfectants for use on the farm. It is readily prepared by slaking lime in water and may be rapidly applied by means of the brush or spraying apparatus so as to reach all parts of the building which have been exposed to the infection. Quick lime is perhaps the best substance for disinfecting the excrement of cattle. The lime not only destroys the bacteria present in such substances but is of some value as a fertilizer when applied to the land.

Lysol is perhaps one of the least poisonous of the commonly used disinfectants. It may be used in 2 to 3-per cent solutions in the disinfection of the reproductive organs of cows after the occurrence of contagious abortion. In the stronger solutions (4 to 5 per cent) it may be used in all cases where formalin would be recommended. It contains a considerable percentage of formalin and is consequently of almost equal value with formalin as a deodorizer. A good disinfectant solution may be prepared by mixing carbolic acid and sulphuric acid at the rate of 1 lb. each of the acid in 5 gal. of water. The vessel containing the carbolic acid should be placed in cold water and the sulphuric acid should be added slowly on account of the fact that much heat is developed in the mixing. The mixture is then added to 5 gal. of water immediately before use. This material is effective and quite cheap.

In outbreaks of disease where stables are badly infested with insects and where the possibility of their carrying disease must be admitted it is desirable to fumigate with sulphur fumes or hydrocyanic-acid gas for the destruction of these pests. Both sulphur dioxid and hydrocyanic-acid gas are effective in destroying pathogenic bacteria as well as insects. In estimating the amount of sulphur necessary for use in a given case it should be remembered that 1 lb. of sulphur burned in 1,000 cu. ft. of space will produce an atmosphere of 1.15 per cent sulphur dioxid. Commercial sulphur contains certain impurities, however, so that 1 lb. may be depended on to produce only a 1-per cent mixture of the gas in 1,000 cu. ft. of space. A 5-per cent

mixture is about what is necessary and therefore 5 lbs. of sulphur may be provided for each 1,000 cu. ft. The effectiveness of sulphur fumigation is lost if the stable is not tightly closed and the gas is less active at low temperatures than at moderately high ones. Sulphur dioxid is rapidly fatal to rats, mice, fleas, lice, mosquitoes, and other insects.

Hydrocyanic-acid gas is extensively used in the disinfection of nursery stock and in the fumigating of orchard trees for insect pests. Its use has recently been extended to the destruction of insect pests in dwelling houses, stables, ships, railroad trains, etc. The gas is much more powerful as an insecticide than as a germicide but is effective against some of the less resistant pathogenic bacteria. Hydrocyanic-acid gas is generated by combining potassium cyanid, 1 part; sulphuric acid, 1.5 parts; and water 2.25 parts. The acid is diluted in water in a receptacle which is capable of enduring the heat produced by the chemical combination. After the acid has been diluted in water the potassium cyanid is added and all openings in the stable must be tightly closed. It should be remembered that hydro-cyanic-acid gas is an exceedingly poisonous substance and causes death rapidly to large animals as well as to insects. It must, therefore, always be used with caution and rooms or stables which have been fumigated should be opened and allowed to ventilate an hour or more before it is safe to enter. In estimating the amount necessary for fumigation 1 oz. of potassium cyanid and 1.5 of sulphuric acid are sufficient for each 100 cu. ft. of space to be fumigated.

In the eradication of animal diseases, reliance must be placed on the thorough disinfection of stables and premises and the isolation of diseased animals. Healthy animals should not be allowed to enter infected stables until after the process of disinfection has been completed. In some instances where the outbreak is of a serious nature and where the stable is old and of little value it may be cheapest in the long run to burn the whole stable and start anew. It is obvious that the most reasonable way of preventing the further spread of the disease to healthy cattle is to remove the healthy animals to fresh quarters and then inaugurate the system of combating the disease in infected stables.

Where healthy cattle have been exposed to infection it may be desirable to take the precaution of disinfecting the skin. For this purpose a number of disinfectants may be used in such a manner as to destroy the pathogenic bacteria without seriously injuring the hair or the skin of the animals. Among the suitable materials for use in this way, mention may be made of carbolic acid, 5 per cent; potassium permangenate, 3 per cent; corrosive sublimate, 0.1 per cent; chloronaphtholeum, 2.5 per cent; and lysol, 5 per cent. These substances may be applied with a brush or with a spraying apparatus and their

application should preferably be preceded by a thorough cleansing of the skin with soap and water.

The Diseases of Cows.

Among the numerous infectious and other diseases to which cows are susceptible we may discuss in this connection the more important ones from the standpoint of milk production and human health. On account of the practical difficulties involved in arranging these diseases satisfactorily according to their etiology or nature an alphabetical arrangement has been adopted.

Abortion.—This term is used to denote premature birth of offspring. It may be due to various causes and is accordingly of a noncontagious or contagious character. Noncontagious abortion may be brought about by excessively cold weather; frozen food; cold storms; blows and other mechanical injuries; moldy, smutty, and unwholesome food; fermentation of food and consequent bloating; confinement in poorly ventilated stables; ergot; irritating drugs; constitutional diseases; undue excitement or worrying with dogs; and from various other causes. These forms of abortion may be distinguished from the contagious form by the fact that the disease does not spread by contact like true contagious diseases but is due to other causes such as have just been mentioned. Where several cases occur in the same herd it will be apparent upon investigation that all the aborting cows have been subjected to the same unfavorable conditions. For preventing these forms of abortion it is necessary that care be exercised in furnishing pure water of a moderate temperature, wholesome feeding stuffs free from smuts, molds, ergot, etc. and by providing stables with plenty of ventilation. Particular attention should be given to these matters during the first few weeks just prior to calving.

Contagious abortion is due to the action of a bacillus or specific contagion which is distributed by means of breeding animals. Mere association in the same herd does not transmit the disease, actual contact is necessary for such transmission. This disease recurs from year to year in the same cows if no treatment is adopted. In cases of the contagious form, abortion may take place during the first 2 or 3 months of gestation and may thus escape detection unless particular attention is given to the subject. The best method of treating this disease consists in a thorough application of disinfectants to the cows, the fetus and the fetal membranes, and stables. For this purpose a 1 per cent solution of carbolic acid or a solution of corrosive sublimate, 1 part in 1,000, may be used as a vaginal wash. The fetus and fetal membranes should be burned or otherwise rendered innocuous. The hind legs and other parts of the cow which have become infected should be treated with antiseptic solutions. For the disinfection of stables the methods previously recommended in discussing disinfection may be adopted. Cows appear to become immune to this

disease after aborting 2 or 3 times. It is desirable to quarantine young cows which have aborted until they become immune and to exercise great care in preventing the introduction of aborting animals into a herd which is free from the disease.

Actinomycosis.—Actinomycosis is an infectious disease characterized by the development of tumors in various parts of the body especially the head. The disease is also known as big jaw, lumpy jaw, and wooden tongue. The most recent investigations indicate that there are 3 forms of actinomycosis due to 3 distinct organisms but producing quite similar symptoms. As a rule, however, only 2 forms are recognized, viz., true actinomycosis and actinobacillosis. Actinomycosis proper is due to infection with a fungus known as actinomyces which produces radiate clusters of fungus threads in different tissues of the body especially in the jaw bones and the tongue. The disease may also appear under the skin of various parts of the body, and in the pharynx, larynx, lungs, and digestive tract. The most characteristic forms of actinomycosis are those which are observed in the jaw bones in which large bone tumors are produced and in the tongue which becomes hardened as a result of the disease and gives rise to the name wooden tongue. Actinomycosis of the lungs may sometimes be mistaken for tuberculosis but may readily be distinguished by a bacterial examination which will disclose the presence of comparatively large radiate clusters of organisms not seen in cases of tuberculosis. The method of infection is still somewhat uncertain although most observers believe that animals become infected with the food. Actinomyces or ray fungus may be found on various plants and it is probable that it gains entrance to the organism of cattle by means of punctures or abrasions of mucous surfaces due to sharp-pointed awns, seeds, or other fragments of vegetable tissue. The infection spreads very slowly and it is not certain that infection takes place directly except in the rarest instances. It seems more probable that the fungus contaminates grasses and other forage plants and thus gains entrance to other healthy cattle. Actinomycosis occurs in man and appears to be identical with the disease observed in cattle. The transmission of actinomycosis to man through the consumption of the meat or milk of the diseased animals has not been definitely demonstrated but it must be admitted that such transmission may take place in rare instances particularly if the mucous membrane of man be weakened by the presence of any disease. In man, as in other animals, the disease appears to arise from some part of the alimentary tract. Decaying teeth are often the point of entrance of the organism.

Actinobacillosis has been reported from South America, Canada, and various parts of the United States. The symptoms of this disease are almost identical with those of actinomycosis proper. A microscopic study of diseased tissue, however, shows the presence of an

actinobacillus. In this form of the disease as in actinomycosis proper the head is chiefly affected particularly the jaw bones.

Anthrax.—This is an infectious disease due to infection with anthrax bacillus and is also known by the names charbon, splenic fever, wool sorter's disease, malignant pustule, etc. It occurs in nearly all warm-blooded animals including man and is distributed throughout the known world. Herbivorous animals are apparently most susceptible. Infection from anthrax may take place through the digestive tract, the skin, or lungs. In cattle infection is most frequent through the digestive tract. The disease appears suddenly with high temperature, carbuncles, edema of the skin, difficult breathing, and cerebral manifestations. During the progress of the disease hemorrhages of varying extent are produced in different parts of the body especially in the submucous, subcutaneous, and subserous tissues. The blood assumes a dark color and tar-like appearance. In acute form the disease usually terminates with fatal results within 2 or 3 days. The bodies of animals which have died of the disease bloat rapidly. Anthrax prevails most extensively in countries which are subject to periodical inundation or flooding from streams. Pools of stagnant water and rivers or small streams contaminated with waste material from tanneries may also carry infection. Contagion is also widely spread through the unburied bodies of dead animals by means of carrion birds and other animals and incests. After an outbreak of anthrax the stables must be thoroughly disinfected and all healthy cattle should be removed from fields which are likely to be infected. In many localities the continued occurrence of the disease has been found to depend upon carelessness in allowing carcasses of dead animals to remain unburned and unburied. Little benefit is derived from medical treatment of this disease. The main reliance should be placed on vaccination which, in the hands of competent veterinarians, has yielded quite satisfactory results. Pasteur's method of vaccination consists in the use of virus of 2 strengths both of which have been attenuated by being grown at a temperaure of 42 to 43°C. for several days. The first vaccination is of low virus and the second is of somewhat greater strength. Another method af vaccination consists in taking the blood from an animal just dead of anthrax, heating it to the boiling point, then dissolving it in water or bouillon and using it for injecting purposes. In man anthrax appears in the form of malignant pustules and is a very dangerous disease. It may be transmitted directly from infected tissues or by means of the milk of animals suffering from the disease. The anthrax bacillus, however, does not usually appear in the milk until the later stages of the disease.

Blackleg.—This is also known as black-quarter, symptomatic anthrax, etc., and is an infectious disease which affects chiefly young cattle between 6 months and 2 years of age. In older animals the disease is much less frequent. Blackleg is a rapidly fatal disease and

was formerly confused with anthrax. It is produced, however, by a specific bacillus which may easily be distinguished from that of anthrax. Blackleg occurs as a stationary disease and is confined almost exclusively to blackleg districts. The period of incubation is about 2 days. The disease may affect cattle, goats, sheep, and horses but is not transmissible to man or hogs. The most important means of diagnosing this disease especially of distinguishing between blackleg, tumors appear under the skin which emit a crackling sound on friction and contain gas. These tumors are most frequently located on the thigh, neck, shoulder, and lower part of the breast. In distinguishing between anthrax and blackleg it should be remembered that in anthrax the spleen becomes greatly enlarged and the blood is not readily coagulable. Anthrax swellings differ from those which occur in blackleg in not containing gas and in causing death less rapidly. Malignant edema closely resembles blackleg the swellings in both diseases containing gases. In general, however, malignant edema arises from a wound of considerable size, while blackleg appears to develop as the result of infection through minute punctures or skin wounds of such small size as not to be readily detected. Blackleg may be successfully combated by preventive vaccination. The Bureau of Animal Industry and various experiment stations have perfected a system of vaccination and have distributed vaccine so extensively that the disease is now well under control and reliable statistics regarding the effectiveness of vaccination are now available. During the past 7 years nearly 8,000,000,000 doses of vaccine have been distributed by the Bureau of Animal Industry and the statistics collected indicate that the losses after vaccination are reduced to less than 1 per cent.

Bloating.—Bloating is also commonly referred to as tympanites, hoven, or bloat. It is of especially frequent occurrence in cows after eating large quantities of feeding stuffs which readily ferment. The disease is characterized by intense swelling of the left side and is due to the formation of gases of fermentation in the paunch. It may be due to eating any kind of feed which causes indigestion or fermentation. When cattle are first turned on pasture of green clover or alfalfa serious cases frequently result until the animals become used to this kind of forage. Bloating may be brought about by eating too hastily as well as by eating too much or too readily fermentable food. Quite frequently the quality of the food is the cause of bloating. Frozen roots or clover wet with dew or frost are generally regarded as dangerous. As a rule, the clovers and alfalfa produce bloating only when eaten in a green condition. A few cases have been observed, however, from eating these plants in the form of hay. Whatever may be the cause of excessive bloating from the use of green leguminous forage it is certain that cattle may become accustomed to eating these plants in a green state so that no bad effects are obtained from

feeding upon it. It may probably be wise at first to allow the cows to remain only for a short time upon such pasture until the danger of bloating is passed.

When bloating is not too far advanced a sufficient treatment may be found in keeping the animal moving for a short time. Where cows are not observed, however, until the paunch is firmly distended it is necessary to adopt some more efficient remedy. Large doses of melted lard, solutions of soda and other alkaline substances sometimes bring about prompt relief but in many instances the stomach may be so distended that puncture or rumenotomy may be necessary. This is almost always necessary if the production of gas has gone so far that the animal is unable to walk. Under such conditions, the distention of the paunch may become so great as to interfere with respiration or the action of the heart or even so far as a rupture of the diaphragm or intestinal walls. In such cases it is necessary to make an incision on the left side of the body at a point about equidistant from the last rib, the angle of the hip bone, and the vertebral column. The incision may be made with a broad-blade knife with one stroke, but more effectively with a trochar and canula which may be readily obtained from dealers in veterinary instruments.

Cornstalk disease.—For many years reports have been received of losses in cattle from feeding in cornfields in various States of the central west especially Nebraska, Kansas, Missouri, Iowa, Illinois, etc. The conditions under which cases of this disease occur vary so extremely that great difficulty has been experienced in determining the cause and nature of the disease. The disease usually appears suddenly. The animal remains apart from the herd, the back is arched upward, and various nervous movements are observed. Sometimes the animal kicks at the abdomen or gives other evidence of internal pains, the gait is uncertain and lameness and paralysis frequently appear before death. In general the course of the disease is from 24 to 36 hours. As a rule, the organs have been found to be normal in post-mortem examinations made after death from this disease. Occasionally, however, hemorrhages are observed upon the coverings of the lungs, heart, and thoracic cavity. No line of treatment has been found satisfactory in controlling this disease. Investigations carried on by the Nebraska Experiment Station show that the stomach contains no trace of active plant principles. It is, therefore, not likely that poisonous weeds found in the cornfield have anything to do with the disease. In some cases the stomachs of cows dead of the disease have shown abnormal amounts of chlorid of potash. In 1901, some of the cornstalks analyzed contained abnormally large amounts of potassium nitrate. In 1902, however, only traces of this substance were found. It is apparent from this brief account, therefore, that further investigations are necessary to determine whether there is any

relation between the presence of large of large quantities of potassium nitrate in cornstalks and the appearance of cornstalk disease.

Recently there is a tendency among investigators to consider cornstalk disease as identical with hemorrhagic septicemia. This position is taken by Moore, Law, Brimhall, and others who have studied hemorrhagic septicemia in Minnesota and elsewhere.

Cowpox.—Cowpox also known as variola of cattle is a contagious disease of cattle which is characterized by a fever, shrinkage in the milk yield, and by the appearance of pustules under the teats and udders of dairy cows. This disease, although of a contagious nature, is quite harmless so far as cattle are concerned and runs a benign course. It is most common in the eastern States. The contagion of cowpox is not spread except by actual contact. Apparently the virus cannot travel through the air. The disease quite frequently attacks horses, appearing upon the heels, lips, nostrils, and other parts of the skin. It may be readily transmitted from the horse to cattle or *vice versa* if the same attendant grooms both cattle and horses. The disease is usually transmitted from one cow to another by milkers who do not cleanse or sterilize their hands after milking an animal affected with cowpox. It has long been known that cowpox may be transmitted to man through wounds or elsewhere and that the mild disease thus produced confers immunity to smallpox. Investigations thus far conducted with reference to the relationship of these diseases indicates that smallpox and cowpox are specifically distinct. Young cows are most susceptible to cowpox but older animals are not immune. The period of incubation varies from 4 to 7 days. At first a slight elevation of temperature occurs and this is followed by the appearance of an inflamed abscess upon the teats, udder, and under the inner surface of the thighs. In some instances the skin of the throat is similarly affected. On the second day after the appearance of the inflammation reddish nodules are found and these gradually enlarge until they attain a diameter of one-half inch or more. The nodules are then gradually transformed into vesicles containing a fluid after which the usual pustule stage is reached with thicker more purulent contents. The usual treatment for the disease consists in careful handling and the application of disinfectant solutions to all ruptured vesicles upon the udder.

Enteritis.—Under certain conditions the digestive tract of cattle may be so severely irritated as to lead to an inflammation of the intestines which is characterized by the production of a false membrane particularly in the large intestine. This form of the disease is known as croupous enteritis. The usual symptoms are depression, loss of appetite, and diarrhea with shreds of false membrane in the feces. The ordinary treatment consists in the administration of Glauber's salts in doses of 1 lb. followed by bicarbonate of soda in 2 oz. doses 4

times daily. Enteritis may also appear as the result of twisting or invagination of the intestines. In such cases there is evidence of severe colicky pains, the animal gets up and lies down frequently refuses food, and is sometimes bloated. There is little hope from treatment in this form of enteritis. Simple inflammation of the intestines in cattle is comparatively rare. The course of the disease is from 4 to 6 days. A similar affection in the horse often proves fatal within a few hours. An ounce of laudanum may be administered in doses of 8 to 12 oz. of linseed oil every 4 to 8 hours.

Hemorrhagic enteritis of calves is a septic disease of uncertain origin which may rapidly run to a fatal termination. In some cases, calves suddenly refuse food, show an elevation of temperature, and die within 12 hours. In this form of the disease hemorrhagic patches are almost always present under the serous membranes. The presence of hemorrhages serves as a ready means of diagnosing between this disease and ordinary diarrhea of calves.

Flukes.—Several species of liver flukes may occur in the bile ducts of the liver of cattle, 2 of which, the common liver fluke and the large American fluke, are known to infest cows in this country. The common fluke is much more frequently met with than any of the other species. Flukes are taken into the body with fodder and water. Cattle most frequently become infested with these parasites when grazing on marshy pastures. In young animals extensive infestation may produce fatal results. The symptoms resemble somewhat those produced by stomach worms. The beginning of the disease is not usually observed. At first there is a diminished appetite and an unthrifty appearance of the skin. The mucous membranes become pale and the eyes somewhat dull. In advanced stages of infestation there are diminutions in the milk supply, unusual thirst, and edematous swellings on the lower portion of the body. In some instances, however, the liver may be infested with the flukes to the extent of the destruction of a large portion of its substance without producing any disturbances in the condition or nutrition of the animal. The common fluke is a leaf-shaped worm with a conical head and flattened posterior portion. It occurs as a parasite more frequently in cattle than in sheep, goats, and hogs. It varies in length from 16 to 41 mm. and in width from 6 to 12 mm. Sometimes the flukes penetrate into the circulation and are carried to other parts of the body where they may be found in the form of tubercles particularly in the lungs. The embryonic stages of the liver fluke are passed in fresh water snails and from these animals the young flukes crawl upon the stems of grasses in marshy places and thus gain entrance to cattle or other animals which serve as the final host of the parasite. Medicinal treatment is usually unsatisfactory. The disease may be prevented, however, to a great extent by drainage or avoidance of marshy places

or by introducing carp and frogs into infected waters. These animals feed upon the snails and thus destroy the flukes in their early stages.

Foot-and-mouth disease.—This highly infectious disease is also known as apthous fever, epizootic aphthæ, and by similar terms. It is of acute nature highly contagious and is characterized by the eruption of blisters in the mouth, on the feet, and between the toes. The disease is so readily spread by means of domesticated animals that in parts of Europe and elsewhere large cattle yards and abbatoirs are almost permanently infected. Cattle and hogs are most frequently affected but the disease also attacks sheep, goats, buffaloes, dogs, cats. and man. Man may become infected by coming in contact with the diseased animals or by drinking their milk. The intestinal affection produced from drinking the milk of diseased animals is of a serious nature. Ordinarily foot-and-mouth disease does not exist in the United States. A recent outbreak, however, called attention to the great economic importance of this disease in the United States and the dangers from its distribution. This outbreak was successfully combated and the disease was entirely eradicated by the stringent measures adopted by the Bureau of Animal Industry. While foot-and-mouth disease is known to be contagious and has been extensively studied for many years, its bacterial cause has never been discovered. The virus from the eruptions of the disease is exceedingly virulent as is also the milk from the affected animals. The period of incubation is from 3 to 6 days. The first symptoms of the disease are chills followed by high fever and the eruption of small vesicles upon the lips, tongue, gums, and other mucous surfaces of the mouth. A redness and inflammation of the feet particularly at the crown of the hoof and between the toes soon appear and vesicles are developed in such locations. After the disease is well established the appetite is seriously affected and an increased salivation is observed. A ropy saliva drips almost constantly from the mouth. The appearance of the disease in the feet is sometimes simultaneous in all 4 feet or may affect only 1 or 2. The udder is frequently or in some outbreaks usually affected and becomes swollen and caked. In cases where the internal organs are affected before the vesicles appear upon the external surface the disease may prove fatal within a short time. It should be a simple matter to diagnose this disease from the fact of its extremely rapid spread, high fever, and the general appearance of blisters upon the mouth and feet. It may be readily distinguished from cowpox by the fact that the eruptions or vesicles are soon ruptured and never form true pustules. On account of the highly infectious nature of foot-and-mouth disease and the ability of the virus to maintain its virulence for long periods outside of the animal body it is necessary to adopt strictest quarantine measures in all outbreaks of the disease and to slaughter and bury or burn all diseased and exposed susceptible animals. The rapidity with which the Bureau of Animal

industry eradicated the outbreak in New England is proof of the efficiency of this method.

Foot rot.—An inflammation of the foot between the claws may be brought about as a result of the operation of several causes. Foot rot may be due to overgrowth of the claws or inward pressure especially where some foreign body becomes lodged between the claws. The disease may also be due to irritation from stable filth leading to a softening or ulceration of the skin between the claws of the foot. At times several cows in the same herd may become affected and in this way the fear of a contagion may arise. Such outbreaks, however, are due to the fact that the same causes operate upon a number of animals maintained under similar conditions. Simple outbreaks of foot rot of this sort may readily be distinguished from foot-and-mouth disease by the absence of fever, the absence of blisters in the mouth, and the failure of the disease to spread to hogs or other animals which are susceptible to foot-and-mouth disease. In cases of foot rot the animal goes lame, has a swelling of the hoof, and consequent separation of the claws. An inflammation may cause the softening of the membrane between the claws and if neglected may lead to the formation of abscesses with considerable suppuration. In the early stages of the disease before pus has buried beneath the horny covering of the foot a thorough cleansing of the affected parts and the application of a 1 per cent solution of carbolic acid or a similar antiseptic will check the disease. Creolin or corrosive sublimate may be used for this purpose. If the pus pocket has been formed underneath the horn of the hoof it is necessary to tear away the horn until the whole pocket is exposed after which the usual antiseptic treatment may be applied.

Hematuria.—Various pathological conditions cause the presence of blood or the coloring matter of the blood in the urine and give rise to a condition known as hematuria or bloody urine. This is a comparatively common affection in some localities especially among cattle which are allowed to graze on marshy undrained pastures. The condition is due, as a rule, to a structural disease of the kidneys or urinary passages. Albumen is present in the urine as well as the red coloring matter of the blood. Where hematuria is due to a severe strain of the loins by fractures, it is naturally associated with lameness or loss of control of the hind legs. In cases where bloody urine is due to the existence of specific diseases such as Texas fever and anthrax these diseases should be readily recognized. Hematuria may also be brought about by eating irritant plants such as hellebore, buttercup, oak leaves, and in some cases from excessive feeding on alfalfa or pea straw. The treatments for this trouble are naturally varied according to the cause. In general the administration of a purgative (1 lb. Glauber's salts) will remove the irritating substances from the intestines and reduce the fever temperature. In cases where it is apparent that an excess of diuretic plants has been eaten it may be desirable

to administer olive oil and laudanum. It may be useful also to apply hot fomentations or some warm protection over the loins.

Hemorrhagic septicemia.—This name is applied to a highly infectious disease due to the action of *Bacillus bovisepticus* which affects cattle and various other species of domestic and wild animals. The organism which causes the disease belongs to the group which produces chicken cholera, swine plague, and septicemia of rabbits. The disease was first described in 1878 and in this country it has been observed in Minnesota, New York, Pennsylvania, South Dakota, Tennessee, Texas, Wisconsin, and the District of Columbia. In Minnesota the State Board of Health has made a detailed study of the disease and has investigated more than 90 outbreaks involving 3,000 animals. The mortality from hemorrhagic septicemia is very high exceeding on an average 95 per cent. The disease is a typical septicemia and the infection apparently takes place through small abrasions of the skin or injury to the mucous membranes from pieces of fodder and from other causes. The usual symptoms are loss of appetite, fever, stiffness, swellings of the legs and throat, a black-tarry excrement, and nervous excitement resembling meningitis. The meningeal symptoms have been observed in a large number of cases. On this account certain investigators believe that some cases of hemorrhagic septicemia have been mistaken for cerebro-spinal meningitis and cornstalk disease, and have passed under these latter names. At present, the majority of students, who have worked with hemorrhagic septicemia, believe that cornstalk disease is merely one form of hemorrhagic septicemia. The chief pathological lesions observed in cases of this disease are hemorrhagic areas of various size in the subcutaneous tissue, muscles, lymph glands, and throughout the internal organs. The spleen is rarely enlarged. According to Brimhall, whose investigations have been followed in this account, a distinct meningitis with an exudate almost filling the spinal canal is observed in all cases which showed meningeal symptoms. The differential diagnosis between hemorrhagic septicemia, anthrax, blackleg, and cerebro-spinal meningitis due to a diplococcus is a difficult matter. A bacteriological investigation, however, should disclose the presence of *Bacillus bovisepticus* in all cases of hemorrhagic septicemia and the presence of numerous hemorrhages in all parts of the body should assist in reaching a diagnosis. Thus far treatment has proved to be entirely without avail. It is necessary, therefore, after outbreaks of this disease to remove and destroy all carcasses, isolate all exposed and sick animals, and apply thorough quarantine measures and disinfection to the premises.

Horn fly.—In localities badly infested with horn flies, cattle are greatly irritated and kept in a state of worry by the attacks of these pests. The horn fly was originally introduced from Europe and has become quite generally distributed over the country. The insect is

somewhat smaller than the house fly but closely resembles it in general appearance. It appears in swarms and has the habit of collecting in great numbers at the base of the horns from which fact its name apparently arises. The horn flies attack cattle especially upon the flanks and shoulders and places where they are not easily driven off by the tail or head. The pest may be combated by applying a mixture of 2 parts crude cotton-seed oil or fish oil and 1 part of pine tar to the flanks, back, and fore quarters. Fresh application should be made at intervals of about 10 days. The swarms of horn flies should also be removed by spraying cattle with kerosene emulsion or a mechanical mixture of crude petroleum and carbolic acid. One of the most successful methods of ridding cattle of horn flies consists in the use of a trap. A covered shed or passage way is provided for the animal to walk through; a well-lighted dome is constructed on one portion of the passage way the rest of which is kept as dark as possible. As the cattle pass along they crowd through a set of brushes which sweep off the flies. After being brushed away from the cows they arise into the lighted portion of the dome where they are captured. Cattle soon learn the purpose of this devise and thus rid themselves of horn flies. A systematic effort is being made to introduce parasites of the horn fly into Hawaii.

Jaundice.—As soon as the condition of jaundice has been established there is a noticeable yellow tinge in the white of the eye and the mucous membrance of the mouth. The same appearance may be observed in parts of the skin which do not bear pigment. Jaundice must be considered as merely a symptom of some disease. An inflammation of the mucous membrane of the duodenum may mechanically obstruct the escape of bile and thus lead to a jaundice condition. In constipation there is a torpid condition of the intestines which leads to the absorption of the bile and a distribution of its yellow coloring matter through the body. Jaundice may also arise from excessive parasitism with flukes or tapeworms in the bile ducts. A congested condition of the liver due to continued high feed and lack of exercise may lead to jaundice. In all cases of this disease it is desirable to stimulate the action of the intestines and thus relieve the congestion of the liver and portal vein. For this purpose the diet should be of a laxative nature and purgatives should be administered such as a mixture of 16 oz. of sulphate of soda and 1 pt. of molasses with 1 qt. of warm water.

Joint ill.—Young calves within the first few months after birth are sometimes affected with a septicemic inflammation of the joints. When once established this inflammation persists and is commonly associated with an infection of the navel. It is thus readily distinguished from rheumatism which rarely occurs at so young an age and which has the tendency to shift from one joint to another. Joint ill is due to infection of the navel cord at the time of birth. The micro-

organisms thus introduced pass through the circulation and lymphatic system and finally become localized in the joints or elsewhere causing inflammations and abscesses. Affected joints are hot and sensitive. The animal is lame, shows a high fever and a purulent discharge from the navel. The liver and various other organs may also be affected. This trouble may be largely prevented by the adoption of proper sanitary precautions. Cleanliness in stables and the use of disinfectants at frequent intervals will destroy the septic organisms which cause the disease. In case of joint ill the treatment should be chiefly antiseptic. In mild cases the affected joint may be painted with iodin or with an ointment of biniodid or mercury at the rate of 1 dram in 2 oz. of lard. If swellings are present containing purulent material this may be removed by the use of a hypodermic syringe and the cavity disinfected with suitable antiseptic solutions.

Keratitis.—On account of the exposed position of the cornea this part of the eye is quite subject to injuries in the way of scratches, lacerations, etc. from sharp pointed stems of forage or from awns or other objects. In cases of diffuse keratitis the cornea becomes opaque from the extension of the process of exudation. Where the whole cornea is affected it shows a uniform grayish-white color. In favorable cases the opacity disappears and the cornea becomes transparent again after a period of 10 days. In more severe cases, however, the vision is entirely lost and the cornea remains permanently opaque. In certain cases suppuration may take place as a sequel of diffuse keratatis. In treating this disease the animal should be placed in a dark stable and purgatives administered. If the health is not vigorous it may be desirable to give a tonic. The affected eye may be treated with a solution of nitrate of silver at the rate of 3 grains to 1 oz. of water. In order to clear up the cornea it may be well to apply twice daily a few drops of a solution containing 15 grains of iodid of potash and 20 drops of tincture of sanguinaria in 2 oz. of distilled water.

Lice.—There are 3 species of sucking and biting lice which are parasitic on cattle. Perhaps the most common species is *Haematopinus eurysternus,* so-called short-nosed ox louse. The presence of this louse in large numbers causes a quite serious irritation of the skin of cattle and thus leads to loss of weight and diminution in the milk yield. The adult female lice are about 1-8 to 1-5 of an inch long and half as broad as long while the males are somewhat smaller. The females deposit their eggs on the hair near the skin. This louse is one of the most difficult parasites to eradicate. Various remedies have been used as dips or washes or by the method of fumigation. Considerable benefit has been derived from the use of carbolic or tobacco sheep dips, kerosene emulsion, extract of larkspur-seeds, ashes, mercurial ointment and fumigation according to a method recommended by Osborn. This method consists in confining cattle in a close box stall merely large enough to admit the cow and furnished with a close-fitting door.

A thick canvass sack is attached to the head of the animal so as to leave merely the eyes and nose exposed. After the apparatus has been arranged tobacco, pyrethrum or sulphur may be burned in the enclosed space for the purpose of destroying the lice. A closely related species (*H. vituli*) occurs on cattle but is somewhat less common. This species and the biting red louse (*Trichodectes scalaris*) infest cattle to a considerable extent. All of these species may be treated in the same manner. Close attention should be given to cattle in order to prevent their becoming too extensively infested with these parasites since the animals may be so irritated as to rub off large patches of hair and lose greatly in condition.

Malignant catarrhal fever.—This is a specific disease of cattle probably due to the action of a micro-organism which thus far, however, has not been demonstrated. The disease appears not to be directly infectious but rather through intermediate carriers such as food and the filth of stalls and cow sheds. The disease usually appears in a sporadic manner and under certain conditions may attain the proportions of a local plague. The parts chiefly affected are the respiratory and digestive tracts, sinuses of the head and eyes. It is much more frequent in Europe than in this country but outbreaks have been reported in New Jersey, New York, and Minnesota. Malignant catarrhal fever prevails most extensively in late winter and spring and affects chiefly young animals. The usual symptoms are chills followed by considerable elevation of temperature, trembling, abundant secretion of tears, swollen eye lids, sensitive eyes, and a general catarrhal condition of the respiratory and alimentary tracts. In mild cases recovery takes place within 3 or 4 weeks. The rate of mortality is very high, however, being as a rule from 50 to 90 per cent of all affected animals. In fatal cases death takes place within from 3 to 7 days. In some cases ulcers may be found on the mucous membranes when post-mortem examinations are made and croupous deposits have been observed in the throat. There is no satisfactory treatment for this disease except the administration of palliative remedies such as antiseptic washes applied to the nose, eyes, and mouth; the administration of calomel in one-dram doses twice daily; and the use of tonics containing ferrous sulphate, quinin, and subnitrate of bismuth Although malignant catarrhal fever is an acute disease of serious character and highly fatal consequences, it is usually found, post mortem, that the essential tissue of the internal organs is unaltered. According to Bollinger this furnishes an important means of diagnosing between malignant catarrhal fever and rinderpest. The meat of animals affected with this disease has not been shown to cause harmful effects when eaten. It is uncertain whether the virus may be excreted with the milk but it appears highly probable that it might gain entrance to the milk as the result of the contamination of the floors of stables with the pathological discharges.

Malignant edema.—Various domestic and wild mammals as well as man may be affected by this disease which is of bacterial origin and of an acute nature. The bacterial cause of the disease is *Bacillus septicemiae gangrenosa.* This organism is anaerobic and rarely found in the blood. Certain investigators including Arloing and Chauveau have claimed that cattle are immune to the disease. Kitt. however, has shown that the bacillus of malignant edema may cause extensive local swellings in cattle. As a rule, malignant edema is rarely met with in cattle but occurs chiefly as the result of infectious wounds of accidental occurrence or due to surgical operations. The pathogenic organism of malignant edema is of wide distribution and occurs in cultivated soil, polluted water, and the alimentary tract of herbivorous animals. The organism remains closely confined to the immediate region of inoculation but after death may penetrate into tissues quite remote from the point of entrance. The symptoms of malignant edema include muscular stiffness, trembling, a rapid weak pulse, high temperature and a hot painful swelling at the point of infection. The swelling emits a crackling sound on pressure. The intestines are usually found in a normal condition and the lungs may be somewhat edematous. Malignant edema closely resembles blackleg but unlike the latter disease never appears as an extensive epizootic but always in isolated cases which may be explained as due to wounds received from various causes. A differential diagnosis between anthrax, blackleg, and malignant edema may be reached by inoculating guinea pigs, rabbits and chickens. All 3 species of these animals are destroyed by the organism of malignant edema while only guinea pigs and rabbits succumb to anthrax and guinea pigs alone to blackleg. Treatment should be mainly surgical and should consist in the incision of the local swellings and thorough treatment with antiseptics such as 5 per cent solution of carbolic acid or 30 per cent solution of peroxide of hydrogen.

Mammitis.—The mammary gland in cows is subject to a great variety of inflammatory and other pathological conditions many of which are grouped together under the term mammitis or mastitis. Mammitis may be either of an acute or chronic nature. Acute catarrhal mammitis is also known as mammary catarrh and consists essentially of an inflammation of the milk ducts and canals. It is, therefore, analogous to bronchitis in the lungs. As a rule the disease is not accompanied by pronounced constitutional symptoms, the affected parts of the udder are hot, swollen, and painful to the touch and occasionally the swelling is so extensive as to partly conceal the teats. The milk is nearly always altered and consists of a pale yellow serum containing clots of casein and other material and is frequently tinged with blood. In the acute form of mammitis the disease appears suddenly and in milder cases may disappear within 6 or 8 days. If the disease runs a slower course it may be complicated with parenchymatous mammitis.

In the latter form of the disease the minute milk canals, acini, connective tissue and to some extent the whole gland is involved in the inflammatory process. This form of the disease is ordinarily complicated with other more dangerous symptoms. Parenchymatous mammitis may be due to various micro-organisms such as *Staphylococcus mammitis, Galactococcus versicolor, G. fulvus,* and *G. albus.* The general symptoms are loss of appetite, bloating, feeble pulse, and elevation of temperature. The local symptoms include an enormous enlargement of the mammary gland and an extension of the swelling forward along the abdomen. The milk in the affected quarters of the udder assumes a yellow color and even the unaffected quarters will be similarly altered within a few days. This form of the disease develops slowly and may, even in most favorable cases, cause an induration complicated with the formation of abscesses or gangrenous processes.

Chronic catarrhal mammitis is due to infection with Streptococcus and is of a highly contagious character. It is also known by the terms streptococcus mammitis, contagious agalactia, and is synonymous with "gelber galt" or Switzerland. In cases of this disease a nodule appears at the base of the teat which gradually increases in size up to that of a man's fist and is surrounded by edematous tissue. At first the milk appears watery and blueish in color and contains leucocytes. Later it becomes viscid and is of a yellowish or pink color. This form of mammitis may be acute or chronic but usually runs a slow course. In milch cows the disease is frequently complicated with inflammation of the joints. The affected parts of the udder become atrophied and transformed into fibrous tissue. On account of the great infectiousness of this disease and consequent rapidity with which it spreads through a herd it is necessary that affected animals be isolated promptly. Prognosis in this form of the disease is nearly always unfavorable. A certain percentage of cases die as a result of chronic abscesses and gangrenous process, while affected cows are scarcely ever useful for milk purposes after recovery. The mammary gland becomes almost or entirely sterile as the result of the disease.

The various forms of inflammation of the mammary gland commonly referred to by dairymen as garget are of frequent occurrence and since many cases do not persist long and do not have any serious conclusions considerable indifference exists toward the treatment of the disease. In heavy milking cows the mammary gland is always enlarged just after calving and may show an elevation of temperature and an increased sensitiveness to touch; the swelling may even extend forward along the abdomen. This congestion usually does not last for more than 2 or 3 days but may sometimes be greatly aggravated by exposure to cold or by neglect on the part of the milkers. In such cases the milk soon shows clots, pus cells, and a red tinge of blood.

Treatment should consist in the copious administration of warm

drinks, the administration of heat to the body, and the use of camphorated ointment, weak iodin ointment or more drastic ointments to the udder. Such application should be accompanied with thorough rubbing. After the swelling and inflammation subside milking should be done with considerable care and gentleness. In cases where fever has already occurred it is well to administer epsom salts in doses of 1 to 2 lbs. and saltpeter in daily doses of 1 oz. In all cases of an infectious nature it is necessary to take great precautions to prevent the spread of infection. If the infected portion of the udder is milked before the other quarters, infection is almost certainly spread to the latter if the hands are not previously washed and sterilized. The habit of milking diseased quarters of the udder upon the floor of the stable should be condemned since the streptococcus is present in such milk in large quantities and abundant opportunities are thus offered for distributing the source of infection to other parts of the udder and to other cattle.

Metritis.—An inflammation may involve merely the uterus or also the neighboring serous coat of the abdomen causing peritonitis. The symptoms of the disease ordinarily appear within 2 or 3 days after calving and consist of chills, coldness of the horns, ears, and legs, and an unthrifty appearance of the hair. The temperature is somewhat elevated, the pulse rate increased, and the appetite is lost. The chill is soon followed by fever during which the mucous membrane of the nose and mouth as well as the eyes appear red. The uterus is evidently more sensitive than under ordinary conditions and discharges a fluid which is at first watery but later becomes yellow and finally reddish or brown, the latter color being due to hemoglobin of the blood. A certain percentage of these cases recover speedily sometimes within 2 days, other cases develop into a chronic form while in more severe cases there is a septic infection terminating in ulceration or gangrene or general septicemia. The treatment for metritis should consist largely in the thorough washing of affected parts with antiseptic solutions. For this purpose permangenate of potash may be used at the rate of ½ oz. to 1 qt. of water. It is ordinarily desirable to give Glauber salts in doses of 1½ lbs. to which 1 oz. of ginger may be added. For reducing the sensitiveness of affected parts an ounce of laudanum may be given mixed with the same quantity of glycerin.

Milk fever.—The term milk fever although generally used for this disease is somewhat of a misnomer since frequently there is no fever during the progress of the disease but on the other hand a subnormal temperature. Parturient paresis or parturient apoplexy are considered as preferable to milk fever as names for this disease. Milk fever is confined almost entirely to high bred cows in good condition and of mature age. It has also been occasionally observed, however, in sows. As a rule the disease occurs only at or immediately following upon the time of calving. Several cases have been observed, however, which

occurred long after this period. The heavy milkers are most susceptible to milk fever and, as already indicated, the disease does not appear at the first and usually not at the second calving but more frequently at mature age. The nature and etiology of the disease have been investigated and discussed by numerous veterinarians but without definite results. The majority of investigators consider milk fever as an intoxication due to the formation of a poisonous metabolic product at the time of calving. The definite location of the toxin has not been established. Recently, however, Delmer succeeded in producing the disease by inoculating animals with small quantities of milk from affected cows. As predisposing causes to milk fever mention is usually made of close confinement in stalls, high temperature, electrical disturbances, constipation, or other digestive derangement, and a plethoric condition due to over feeding. The symptoms vary according to the form of the disease. In the so-called congestive form of milk fever there is sudden dullness, nervous movements of the hind legs, staggering weakness followed by complete inability to stand. The head and the ears become hot, the cow lies on her breast bone with the nose against the right flank. In the torpid form of milk fever there is no evidence of heat about the head and the attack appears more slowly. The cow soon lies down, however, and is unable to rise. There may be a subnormal temperature and complete or almost complete unconsciousness.

Until recent years the treatment adopted for milk fever consisted largely in the use of purgatives, ice packs on the head, and the administration of tincture of aconite until the fever disappeared. After this treatment, stimulants such as nux vomica were given until the affected cow was able to stand. A large percentage of cases were lost by this treatment, however, and it was not until Schmidt devised his treatment which consists of injecting 10 gm. of iodid of potash into the udder that recovery was brought about in a large percentage of cases. Occasionally a second treatment with iodid of potash was required. Recently still better results have followed the distention of the udder with oxygen or ordinary filtered air. This treatment has the advantage of great simplicity, ease of application and quickness of results. In ordinary cases improvement is noted within a few minutes and recovery usually takes place within from 2 to 6 hours. The udder should be tightly distended with air previously passed through absorbent cotton to remove all dust and bacteria. Good results have utes and recovery usually takes place within from 2 to 6 hours. The tion or with boiled water. The symptoms of paralysis observed in milk fever appear to indicate a condition of extreme anemia of the brain. The beneficial results which appear so promptly after the distention of the udder with such inert substances as air and boiled water indicate that the general blood pressure may perhaps be restored by the increased internal pressure of the udder due to artificial treatment.

Milk sickness.—In the heavily timbered lands and marshy areas of Georgia, North Carolina, Tennessee, Pennsylvania, Ohio, Michigan, and other central States an apparently infectious disease has long prevailed under the name milk sickness. The nature of the disease is not understood but it is usually considered as infectious on account of the fact that it is readily transmitted in the milk. Milk sickness may be readily transmitted, by means of the milk, to man and other animals with serious results. A curious fact noted in connection with this disease is that in milch cows during the period of full lactation no symptoms may be observed unless the animal is driven or violently exercised. After such treatment the animal trembles and shows in a mild form the usual symptoms of the disease. In bulls, steers, and dry cows the symptoms are much more serious. At first the affected animal appears lazy and stands apart from the herd with drooping ears. There is great thirst and constipation. As the disease progresses muscular weakness becomes very pronounced until the animal is unable to stand, the legs and surface of the body appear cold and the animal is indifferent to his surroundings. The stupor gradually merges into complete coma with death on the eighth to the tenth day. Similar symptoms are observed in man after drinking milk of affected cows. The rate of mortality is high. In cases which do not die recovery takes place very slowly. No specific treatment has been devised for this disease. Fortunately, however, milk sickness seems to disappear as soon as infected timber lands are partially cut out so as to allow free access of air, and infected marsh lands drained. The disease formerly prevailed much more extensively than at present.

Mycosis.—There are a number of pathogenic fungi which affect cattle producing inflammatory conditions of the mucous membranes and other structures and commonly referred to under the name mycosis. Recently Mohler has described a mycotic stomatitis of cattle which is of a sporadic and noninfectious nature and which attacks cattle of all ages on pasture especially milch cows. The mucous membrane of the mouth becomes inflamed and later ulceration appears, secondarily the feet may become swollen and frequently erosions are observed on the nose, udder, and teats. The disease is due to feeding on moldy or fungus-infected forage. Apparently several fungi may be concerned in the production of mycotic stomatitis. It is readily distinguished from foot-and-mouth disease (which it may resemble in some of its symptoms) by the fact that it is not infectious and, therefore, does not spread from affected cows to sheep or pigs which may be associated with them. The treatment of the disease should consist first in the removal of cattle from the pasture where the disease was acquired and feeding them upon soft foods until the mucous membrane of the mouth may be restored to a healthy condition by means of washes of borax, potassium chlorid, carbolic acid, creolin, lysol, or permangenate of potash. Quaranta observed cases of asper-

gillosis in the lungs of cattle. The disease was due to a pathogenic aspergillus and produced tubercles which superficially resembled those of tuberculosis. In Pennsylvania Pearson and Ravenel studied a case of this disease due to *Aspergillus fumigatus*. The case occurred in a Jersey cow which had been failing for 6 month and finally died. An examination of the lungs showed that they were greatly distended and contained tubercles due to the action of the pathogenic fungus. The term mycosis may also be used to denote the pathogenic effects of smuts, molds, and rusts which produce more or less serious digestive disturbances without causing specific lesions in other parts of the body. The cause of disease produced by these fungi should be readily detected and after being detected it may be readily removed.

Nagana.—This is an infectious disease due to a protozoan blood parasite of the genus Trypanosoma. The majority of investigators including Laveran and Mesnil consider nagana as a specific disease affecting cattle and horses and distinct from surra, mal de caderas, and other related diseases. The conclusions of Musgrave and Clegg from work done in the Philippine Islands are directly opposed to this view. According to Musgrave and Clegg it is highly probable that surra, nagana, tsetse-fly disease, dourine, bovine surra, etc. are merely different names for one and the same disease which they prefer to call surra. Without entering into this controversy it may be stated that nagana is apparently transmitted from one animal to another by the bites of flies, fleas, or other insects with similar habits and that other methods of transmission may be disregarded as unimportant. It appears to be impossible for the parasitic organism of nagana to pass through sound mucous membranes of cattle and pastures can not, therefore, become infected in the ordinary sense of the word but only in so far as they are infested with tsetse flies and other insects which may carry the organism of nagana. The chief symptoms of nagana are high fever, progressive anemia, weakness and swelling about the head, legs, and abdomen. The disease runs a slow course lasting from 1 to 6 months in cattle and affects various other animals including mules, camels, dogs, etc. The spleen, lymphatic glands, and liver become enlarged and diagnosis is rendered certain by finding the protozoan parasite in the blood. No treatment thus far adopted has proved successful.

Nephritis.—The kidneys may be affected with various forms of inflammation and may thus give rise to different symptoms of varying degrees of importance. The causes of nephritis are as varied as the forms of the disease. Irritant drugs, diuretic plants, exposure to severe climatic changes, blows, and other injuries may lead to some inflammatory condition of the kidneys. In cows which are not in a fat condition the kidneys are particularly exposed on account of the fact that they lie in close contact with the muscles of the loin. Severe exercise or worrying by dogs may also be the cause of a case of neph-

ritis. It has been observed that certain forage plants rich in nitrogenous substances such as vetches, pea straw, and other leguminous plants may occasionally irritate the kidneys to such an extent as to cause inflammation with symptoms of bloody urine. The symptoms of nephritis vary greatly. In some cases they are quite manifest while in others it is almost impossible to locate the affected part. In the cases which are due to blows the disease usually runs a regular course without serious complications. If evidence is obtained that nephritis is due to faulty fodder the diseased condition may obviously be corrected by a change of food. In all cases the first consideration is the removal of the cause. Attention must be given to the exclusion of acrid or diuretic plants from the diet. Sprained loins may be poulticed and the affected cow should be kept in a warm, dry building and covered with blankets if necessary. If fever is present it may be checked by the administration of tincture of aconite in doses of 15 drops every 4 hours.

Nodular disease of the intestines.—A disease of cattle characterized by progressive anemia and diarrhea during the later stages is caused by an intestinal worm known as Oesophagostoma inflatum. This parasite occurs in Europe and in various parts of the United States. Several outbreaks of the disease have been studied in Missouri by Drs. Connaway and Luckey. The disease is most prevalent among calves and yearlings. In cases of mild infestation the chief symptoms observed at first are slight loss of condition and extra feed requirements. During the later stages of the disease emaciation progresses more or less rapidly and after 8 to 12 weeks may result in extreme anemia, diarrhea, and death. Diarrhea does not usually appear until within 5 to 15 days before the death of the animal. The symptoms of the disease are most pronounced when cattle are on dry feed. A partial recovery may take place if the animals are turned on good succulent pasture. The parasitic worm is found in considerable numbers in the intestines of infested cattle particularly in the colon and cecum and what appears to be the larval parasite of this species occurs in nodules in the walls of the intestines. Preventive treatment is the most important consideration in the control of this disease. Animals from infested areas should not be introduced into a herd without a preliminary period of isolation or quarantine. The parasite may infest in a permanent manner certain marshy pastures and from such sources healthy cattle may readily become infested. Drainage and cultivation of such areas is an efficient preventive remedy. No medicinal remedies have proved effective in the control of this disease.

Osteomalacia.—In certain regions a brittleness or softening of the bones in cattle is observed giving rise to a disease known as osteomalacia or creeps. The latter name refers to the uncertain gait which characterizes affected animals. The disease appears for the most part

in adult animals and is due to a decalcification of the bones which renders them more spongy. The periosteal covering of the bones is easily stripped off. Milch cows seem to be particularly susceptible to the disease probably on account of the fact that unusual demands are made upon their nutritive powers during pregnancy and lactation. A pronounced emaciation gradually appears with the symptoms of depraved appetite and intestinal catarrh. J. W. Parker investigated this disease in certain regions of Texas where it appeared to occur as the result of improper nutrition. In advanced cases the skin was dry and tense and animals' ribs had been broken by pressure in lying down or other strains. Some of the affected cattle were parasitized by stomach worms but these parasites could not be considered as the sole cause of the disease. According to Parker creeps must be considered as due to a lack of essential elements particularly lime in the soil. The treatment to be recommended consists in a change of food and the addition of lime salts to the ration. Abundant grain feed should be given including beans, cowpeas, cotton-seed meal, or wheat bran. It may be desirable also to use phosphorus in 1 grain doses twice daily. Some benefit is to be derived from the change of pasture and the administration of common salt and bone meal.

Pericarditis.—An inflammation of the pericardium or heart sac is sometimes associated with rheumatism, pneumonia, pleurisy, and injuries. It apparently occurs also as an independent disease following severe exposure to inclement weather. The symptoms include chills, fever, dullness, hard pulse, quickened breathing, and muscular spasms, the heart beat is usually loud and its peculiar character may be noted by placing the ear against the chest. After fluid has collected in the pericardium the sound of the heart beat is partially lost and is replaced by a churning sound. When pericarditis occurs in association with rheumatism or other diseases the treatment should be such as will counteract these diseases. It is particularly to be recommended that the animal be kept in a warm place and bandaged so as to furnish protection against the loss of animal heat. In cases of pericarditis which result from penetrating wounds from the first stomach little help can be furnished by medicinal treatment. Such cases may arise as the result of the puncture of the pericardium by sharp bodies which have been swallowed with the food. In mild cases not due to puncture and not complicated with serious pleurisy, it is desirable to give a purgative and laudanum in 2 oz. doses provided there is evidence of great pain. Otherwise the laudanum should not be given on account of its constipating effect.

Peritonitis.—Cattle are less susceptible to peritonitis than horses. The usual cause of the disease is to be looked for in wounds of the abnominal wall, intestines, stomach, or uterus. Peritonitis may result as an extension of metritis or enteritis. It also frequently follows upon castration where no antiseptic precautions are taken. The

symptoms are chills, uneasiness, undue sensitiveness of the abdomen, dry muzzle, loss of appetite, hard pulse, and constipation. In animals dead of the disease the lining membrane of the abdomen and intestines is reddened and a reddish watery fluid is observed in the abdominal cavity. Peritonitis which arises as a result of wounds should be treated by applying antiseptics to the wounds and by the administration of opium in doses of 2 to 3 grams followed by rectal injections to prevent too great constipation. Borax in 6 oz. doses has been recommended by Harms. The diet should be of a laxative nature and the body should be kept warm by blankets.

Pleuro-pneumonia.—This disease is generally distributed throughout Europe and other parts of the world but has not been observed in the United States since 1892 when the last outbreak was eradicated by the Bureau of Animal Industry. The bacterial cause of pleuro-pneumonia is not known. Infection may be carried either by diseased cattle or by attendants, feed, dogs, and by other means. The disease is essentially due to inflammation of the lungs and pleura and affects cattle only. No good evidence has been presented to show that the disease may be transmitted to man either by eating the meat or drinking the milk of affected animals. The period of incubation in pleuro-pneumonia ranges from 3 to 6 weeks. The symptoms vary considerably in different cases. In acute cases they appear suddenly with rapid and difficult breathing accompanied with moans and other evidence of pain. The back is arched, the head extended, and the temperature ranges from 104 to 107° F. In very mild cases there may be a cough for a week or more before an elevation of temperature occurs. In such cases recovery may take place. The rate of mortality varies from 10 to 50 per cent and in general from 80 to 90 per cent of the herd becomes affected. The prevention of the disease must depend largely on the effective maintenance of quarantine and the destruction of diseased animals. If an outbreak should occur in a herd it is highly important that all affected animals be immediately slaughtered and destroyed in a sanitary manner after which the stables and exposed parts of the premises should be thoroughly cleaned and disinfected. Medical treatment is of no avail.

Poisons.—Cattle like other domesticated animals are subject to mineral and plant poisons of various sorts. In this connection brief notes may be given on some of the more common sources of poisoning. Some cases of mineral and plant poisoning arise from the injudicious administration of drugs while others are of accidental origin or arise from grazing on poisonous plants in the field.

On account of the extensive use of Paris green and other arsenical preparations for destroying insects and for dipping animals opportunity is frequently offered to cattle to become poisoned with these substances. In some cases also arsenic is used excessively for a tonic or in so-called condition powders. The symptoms of acute poisoning

from arsenic are those of colic, restlessness, and frequent getting up and lying down, the abdomen is senstitive, and violent diarrhea follows in a few hours. In chronic poisoning with arsenic the symptoms resemble those of chronic intestinal catarrh. The best antidote for arsenic is a solution of hydrated oxid of iron which may be made by mixing a solution of sulphate of iron with 1 oz. of magnesia in one-half oz. of water. This dose may be repeated if necessary. The solution should contain 4 oz. of sulphate of iron.

Lead poisoning may occur as the result of licking freshly painted surfaces or from the administration of excessive doses of sugar of lead. The symptoms are dullness, colic, loss of muscular control, convulsions, bellowing, and delirium. Quite recently cases of lead poisoning occurred in Utah as the result of feeding sugar-beet pulp which had lain in contact with pieces of lead ore in freight cars. Treatment should consist in the administration of purgatives, bromid of potash, and dilute sulphuric acid in ½ oz. doses. Occasionally cases of poisoning are noted as the result of eating copper salts, zinc, phosphorus, mercury, mineral and vegetable acids, alkalis, kerosene, carbolic acid, saltpeter, and overdoses of vegetable alkaloids. These cases, however, are of such rare occurrence that they need not be described in this connection. The drug which is perhaps most commonly given in cases of fever is aconite. This produces a paralysis of the motor and sensory centers of the brain and spinal cord, depresses the action of the heart, and in overdoses causes death by paralysis of respiration.

Among the various plant poisons which may be taken by cattle while grazing in the field a few of the more important may be mentioned. Loco weeds occur throughout the States and Territories west of the Mississippi River and especially in the southern portion of this large area. They cause numerous cases of poisoning among cattle but such cases are not so frequent as in sheep and horses. The symptoms are indicated by the name of the plant which means crazy weed. Affected animals usually separate from the herd and indicate in various ways a loss of muscular control and defectiveness of the special senses, they become frightened at common or imaginary objects and sometimes develop vicious and dangerous tendencies. The proper treatment consists in the removal of cattle from areas in which loco weeds grow and feeding with nutritious cultivated fodder plants. In various parts of the Rocky Mountain and Pacific Coast States, pastures are infested with aconite and larksupr. In certain parts of the Wasatch Mountains of Utah a large number of cattle are annually lost as the result of eating common aconite (*Aconitum columbianum*) which grows abundantly in clusters of bushes which line the small streams and in bunches of coarse grass, etc. This species of aconite paralyzes the vagus nerve and thus increases the force and rate of the pulse. The sensibility of the animal is not much affected but

death is ultimately caused by paralysis of respiration. Various species of larkspur especially *Delphinium bicolor* and *D. glaucum* cause losses among cattle in mountain pactures. These plants cause symptoms similar to those produced by over doses of aconite, the gait becomes stiff and irregular, the muscular control is lost, and the animal finally falls to the ground in convulsions. Water hemlock (*Cicuta maculata* and *C. occidentalis*) causes the death of cattle with violent symptoms if the base of the stems and roots are eaten. The symptoms are the manifestations of severe pain, running away from the herd, cerebral frenzy, weak pulse, rapid breathing, and violent muscular spasms. A large number of other plants such as death camas, lupines, etc. occasionally poison cattle but a discussion of these plants would occupy too much space for present purposes. In case of poisoning the best remedy which can be suggested is the administration of permanganate of potash dissolved in water in doses of 30 to 50 grains. This drug if administered immediately after the symptoms appear oxidizes and renders inert those portions of the poisonous plant which still remain in the stomach. The other symptoms must always be combatted by proper remedies such as chloral hydrate, morphine, or Indian hemp for violent convulsions, aconite for a too rapid and hard pulse, strychnin or atropin for a weakened and irregular pulse.

Among the fungi which may poison cattle we may mention a few common examples. The poisonous effects of ergot appear chiefly in the spring of the year. This fungus develops in the heads of certain grasses such as wild rye grass, prairie June grass, several species of couch grass, blue joint, etc. Cattle seem to be slightly more susceptible than other animals to the effects of ergot. It has the effect of contracting the muscles of the small blood vessels and stopping the circulation particularly about the ankles. The tissue below the affected point does not receive the blood supply and consequently dies and sloughs off as a result of gangrene. There is no satisfactory medical treatment. Chloral hydrate has the effect of dilating the blood vessels and the main reliance must be placed on the removal of the cause, viz., the ergotized feed.

In a few instances smutty oats have been fed with serious results. In one case one-half of a large herd of dairy cows died with symptoms of gastritis and with cerebral excitement within 24 hours after feeding on oat hay which was excessively smutty. The conditions under which smutty, rusty, or moldy forage produces diseases are not thoroughly understood.

Rabies.—This disease affects dogs most frequently but all of the domestic animals and man are susceptible. As is generally well known rabies or hydrophobia is transmitted through the agency of bites of affected animals, usually dogs. The frequency of cases in cattle naturally varies from year to year and according to the freedom of access which rabid dogs may have to the cattle. Occasionally it

may happen that a rabid dog bites several cattle belonging to the same herd and in such instances the disease appears after the usual period of incubation which varies somewhat in different individuals. In cattle the disease usually assumes the more violent type but in some outbreaks dumb rabies or the paralytic form prevails, the animals become restless and irritable, the eyes are inflamed, prominent, and with dilated pupils. Animals bellow as if in pain, twitch the tail, and sometimes attempt to bite. In the dumb form of rabies in cattle there is evidence of paralysis with symptoms of nervous exhaustion, dullness, and lameness in the legs. In certain parts of Kansas and other western States several outbreaks of rabies have recently occurred on a quite extensive scale. The cause was apparently to be sought in homeless dogs which were allowed to wander about at will. Rabies may be readily distinguished from tetanus by the fact that in the latter disease the animals are affected by long continued muscular spasms and do not show any signs of viciousness. Treatment for this disease is useless after the symptoms appear. If the biting of cattle by dogs is observed the wounds should be immediately cauterized with a hot iron, with zinc chlorid in a 10 per cent solution or strong nitric acid, otherwise affected animals must be ultimately destroyed. The Pasteur method of treatment which has proved so valuable in preventing the disease in man would probably be effective in treating cases of cattle but would be a very tedious and expensive method.

Retention of the afterbirth.—This trouble affects various domesticated animals but is most frequently observed in cows. The cause of this is to be sought in the firm connections between the fetal membranes and the uterine walls. The symptoms of the trouble may be readily observed since the membranes are ordinarily visible and emit a disagreeable odor. If no attention is given to the cow septic troubles may appear and lead to serious disease or death. Treatment should consist in the careful removal of the afterbirth, the administration of laxatives such as Glauber salts in 1½ lb. doses and ergot in doses of 1 oz. to produce uterine contractions. Thorough antiseptic treatment should then be applied with 1 per cent solutions of carbolic acid or solutions of permanganate of potash, corrosive sublimate or other disinfectants.

Rheumatism.—This is a constitutional disease apparently due to an abnormal condition of nutrition and is characterized by lameness, stiffness of the joints, swellings, and fever. The joints are the parts most frequently affected and the disease may assume an acute or a chronic form. The causes usually assigned for the origin of rheumatism are exposure to cold or dampness especially when the animal is overheated or after severe exercise. Rheumatism sometimes appears without apparent cause or it may follow as one of the consequences of some other disease such as pleurisy. In the chronic form of rheumatism of the joints there is a tendency for the swelling to shift about

from one joint to another. In acute articular rheumatism the symptoms appear suddenly, thirst is usually increased, respiration and pulse are exhilarated, and the temperature rises sometimes to 108° F. In the prevention of rheumatism attention should be given to the physical comfort of the animals and the protection against cold and moisture particularly in buildings. The ration should be compounded so as to furnish variety and abundance of nutritive elements. In chronic rheumatism local treatment may be administered together with tonics. The local treatment may consist in hot or cold packs, friction and liniments, or blisters according to the severity of the case. A system of constitutional treatment is sometimes adopted involving the use of sodium salicylate in doses of ½ oz. every 2 hours and repeated 4 or 5 times until relief is obtained.

Rinderpest.—This disease is known under various names such as cattle plague, rinderpest, contagious typhus, steppe murrain, etc. This has been known for centuries in Europe and Asia but does not occur at present within the limits of the United States proper. It has caused serious ravages, however, in the Philippines. The disease is of a highly infectious nature but its bacterial cause is not known. The virus may be transmitted from healthy to diseased animals in the excreta and discharges from the body or may be carried on the shoes or clothing of attendants. The digestive organs are chiefly affected. The period of incubation varies from 3 to 9 days. The first symptoms are high fever, chills, and rapid pulse. The animal shows great debility, drooping of the head and ears, and dry muzzle, the back is arched, and the forelegs are drawn under the body. As the disease progresses the mucous membranes of the digestive and respiratory organs become greatly inflamed. Upon post-mortem examination reddened spots with diseased and dead tissue or ulcers are observed in the various parts of the alimentary tract and similar changes may be found in the mucous membrane of the respiratory organs. No successful treatment for the disease has been devised. If an outbreak should occur it is desirable that the strictest quarantine measures be immediately put in operation and all affected animals should be slaughtered and rendered innocuous. Susceptible animals may be inoculated with pure bile from an animal just dead of the disease or by glycerated bile followed by inoculation with virulent blood or pure bile or finally by simultaneous inoculation of virulent blood and serum. An active immunity is thus brought about in inoculated animals which persists until all danger from the outbreak is passed. In fact in experiments in South Africa is appears that such immunity persists for about 4 years.

Ringworm.—Various parasitic fungi may attack the skin of cattle. Ringworm is a skin disease due to a fungus of this sort usually known by the name *Trichophyton tonsurans.* The fungus attacks the outer layer of the skin and the hair and may be readily transmitted from one

animal to another. The disease is therefore highly infectious. Affected cattle may be recognized by the circular bare patches on the skin. These patches become inflamed and later show a slight exudation followed by the formation of pus. The bare patches are due to the fact that the fungus causes the hair to break off at the surface of the skin. One form of ringworm which affects cattle and may be transmitted from cattle to other animals or even man is due to another fungus *Achorion schonleinii*. The crusts over the patches in this form of the disease are pale or sulphur color later becoming darker. This form of the disease may be recognized by the peculiar mousey odor of the patches. In treating ringworm the crusts should be removed by means of a brush and soap suds after which acetic acid may be applied or tincture of iodin, sulphur ointment, or similar antiseptic substances.

Scabies.—Mange or scabies in cattle is a parasitic disease due to the presence of a mite in the skin. The disease has long been known among cattle of the southwest and affects cattle quite generally throughout the Rocky Mountain region. It is especially prevalent among range cattle since the best opportunity for infection is found among cattle managed in this way. Scabies appears most prominently in winter or spring especially when cattle are in poor condition or on dry feed. After affected animals have been for sometime on cut grass and have improved in condition the infection with the mange mite may not be apparent. It has often erroneously been assumed on this account that scabies does not affect fat cattle and that spontaneous recovery may take place. This assumption has had the unfortunate result of spreading infection more widely than would have been the case if it had been recognized that such animals are still mangy. The first symptoms are evidence of itching and rubbing especially in the region of the neck and shoulders. The mange spreads gradually along the back and sides but does not ordinarily occur on the inside of the legs or on the less-thickly covered portions of the abdomen. The coat looks rough and does not shed off so readily or smoothly in the spring. After the hair comes off from badly affected patches the bald area apparently gets well and the hair grows again. After one mangy animal is introduced into the herd the disease spreads quite rapidly especially if they are maintained in close quarters. Scabies may be best treated by dipping. Hand dressing has given excellent results in Montana and elsewhere but as a rule dipping in cages or vats is to be recommended. In the choice of a dip it is best to fix upon a mixture of lime and sulphur. There are several objections to the proprietary coaltar dips such as a disagreeable odor, variations in composition, poisonous and irritant effects, and expensiveness. Ordinarily such dips cost 2 or 3 times as much as the lime and sulphur dip. Mayo on the basis of extensive experience with scabies in Kansas recommends that a dip be made so as to contain 12 lbs. of lime and

20 lbs. of sulphur for each 100 gal. of the mixture. This mixture should be boiled for 2 hours in about 25 gal. of water after which it is diluted. The sediment may be mixed with the dip since the whole mixture appears to be more effective when the sediment is included, and is not injurious to cattle. Cattle affected with scabies or exposed to the disease should be dipped in the fall or in the spring. The dip should be maintained at a temperature of 110° F. and the dipping should be repeated 10 days after the first operation.

Scouring.—Indigestion involving some form of scouring is a frequent trouble in calves. The disease commonly referred to by this name may be of a simple or contagious nature. Scouring in skim milk calves may be due to feeding sour fermented milk which has developed injurious properties as the result of uncleanly handling. In sucking calves the disease may be due to abnormal composition of the cows' milk as the result of eating improper rations or irritant drastic plants. Under abnormal conditions in the cow the milk may become greatly changed in composition and may exercise a strongly laxative effect. In slight cases of scouring it is sufficient to give attention to the cause of the disease, prevent undue fermentation in the milk, or improve the rations of the cows. Rye bran may be added to the milk of scouring calves and exercise a good effect upon the alimentary tract. Good results are had from adding formalin to the milk at the rate of 1:1000. The most acute and deadly form of diarrhea in the new-born calf is commonly called contagious scouring or white scours and results in death within 24 to 36 hours. The symptoms are weakness, prostration, rapid breathing, subnormal temperature, and offensive discharges. This form of the disease usually appears during the first 2 or 3 days of life. It is due to infection with a bacterial organism belonging to the group of hemorrhagic septicemia. The organism gains entrance to calves through the unhealed navel cord at the time of birth or soon afterward. No successful treatment is known for white scours. In preventing the disease attention should be given cleanliness of stables, disinfection of the navel of calves after birth, and the disinfectant treatment of cows.

Screw-worm fly.—The screw-worm fly may be distinguished by its blue body, red anterior portion of the head, and 3 black lines on the thorax. It is generally distributed throughout tropical and temperate America. The adults deposit their eggs in refuse matter, flesh wounds, carcases of animals, and other similar material. The eggs hatch within a few hours and the larvæ grow to maturity very rapidly. The larva of this pest is one of the most important insects which affect cattle and other domestic animals. In some parts of the southern States it is absolutely necessary that wounds of cattle be attended to in order to prevent their infestation by this pest. In some cases it appears that the screw-worm fly may deposit eggs upon the skin of cattle where the ticks have been crushed. In order to prevent the

adults of the pest from depositing their eggs in wounds the latter should be treated with dilute solutions of carbolic acid and subsequently coated with pine tar or some other substance which repels the insects.

Staggers.—The term staggers has been applied to various forms of meningitis and encephalitis and has also been used as synonymous with frenzy, coma and other similar conditions observed in cattle. In some localities mad staggers, sleepy staggers, and grass staggers have been used as common terms for what is apparently the same disease. Staggers may be due to severe blows on the head, brain tumors, ergot or other deleterious matters in the food, excessive infestation with parasites, ingestion of mineral and narcotic poisons, severe exertion, or excitement. The first symptoms of importance are those of frenzy, but usually the animal is sleepy and shows but little inclination to move, trembling and muscular spasms followed by delirium and bellowing or staggering. Recoveries from this disease are quite rare even when the best attention is given. When the pulse is hard it may be well to bleed the animal. Epsom salts may be administered in 1½ lb. doses and attention should be given to the animal during convulsions to prevent it from suffering injuries.

Stomach worms.—Calves as well as sheep and goats are frequently infested with a stomach worm known as *Strongylus contortus.* The symptoms of infestations are not characteristic and are not always the same. There are usually digestive disturbances accompanied at first by constipation and later by diarrhea; the appetite becomes irregular and depraved. Infestation with the parasite may come about through contaminated feed and water. Apparently marshy pastures may be important sources of infestation. The treatment recommended by Stiles consists in the administration of 1 per cent of coal tar creosote in doses of 5 to 10 oz. for calves, 1 pt. for yearlings, and 1 qt. for adult cattle. Almost equally satisfactory results may be obtained from the use of gasolene in doses of ½ oz. for calves, 1 oz. for yearlings, and 1½ oz. for adult cattle. In general it is desirable that the gasolene treatment be given only after a period of fasting from 12 to 18 hours and that no water be given for at least 2 hours after the gasolene has been administered. Wheeler obtained excellent results from the use of a 1 per cent solution of lysol and other coal tar products in doses of 6 oz. These remedies may be administered in the form of a drench. For this purpose the animal may be left standing on all 4 feet or may be thrown according to the docility of the animal. In preventing stomach worms attention should be given to the pastures. Marshy pastures should be drained and water should be supplied to cattle in troughs rather than allowing them to secure it from pools which may become infected.

Stomatitis.—Necrotic stomatitis also known as calf diphtheria is a highly contagious inflammatory condition of the mouth occurring

chiefly in young cattle and characterized by the presence of ulcers or necrotic patches and by constitutional symptoms due to the toxins caused by the pathogenic organism. Recently many cases of the disease have been reported in Colorado, South Dakota, and Texas and have commonly been referred to as sore mouth. The disease is due to infection with *Bacillus necrophorus*, is highly pathogenic for cattle, horses, hogs, sheep, rabbits, and various other animals. The chief lesions in necrotic stomatitis are observed in the mucous membrane of the mouth and pharynx. They may extend, however, to the nasal cavities, larynx, trachea, and lungs. Infection apparently takes place through an abrasion in the mucous membrane. Symptoms may be local or constitutional the latter being due to toxin. The period of incubation varies from 3 to 5 days and the first symptoms are dripping of saliva from the mouth followed by a formation of a sharply outlined necrotic patches of the mucous membrane of the mouth. With the appearance of general symptoms the temperature may arise to 104 to 107°F. The disease spreads with great rapidity in affected herds and in acute cases runs its course in from 5 to 8 days followed by death in a large percentage of affected animals. Spontaneous recoveries are rare. For preventing the disease chief reliance must be placed on the separation of sick animals, disinfection of the mouth and nasal passages of all diseased animals, and disinfectant measures applied to stalls and buildings. Treatment of diseased animals consists almost entirely in the careful and thorough cleansing and disinfection of all diseased parts of the mouth and nasal passages. For this purpose a 1 per cent solution of carbolic acid may be used or Lugol's solution containing 1 part of iodin, 5 parts potassium iodid, and 200 parts water.

Teat Disease.—The teats of cows may become injured as a result of chilling in winter, from contact with stagnant, filthy water, or from lying in unclean stables. Similar injuries may be produced by the calf. These injuries may be of a very slight nature or may result in chapping, with the formation of cracks or sores, and in some instances in inflammation of the udder to such an extent as to resemble a serious case of mammitis. This form of trouble is best treated by applications of vaseline or a combination of spermaceti and oil of sweet almonds in equal parts. Where the affected parts are greatly irritated, it may be well to use a wash containing one dram of sugar of lead in one pint of water.

The milk duct may become closed as a result of concretion of casein, the formation of calcareous deposits from the milk, the development of warty or other growths inside of the duct, the thickening of the inner mucous membrane, or the transverse growth of a thin membrane. These troubles usually arise during the later stages of lactation or while the cow is dry. An obstruction in the milk duct may best be removed by the use of the spring dilator or some form

of milk tube, with which all dairymen are provided. Care should be exercised in introducing any instrument into the milk duct, since infection may easily be carried on unclean instruments and may result in the development of mammitis.

Texas fever.—This disease is also known as Spanish fever, Southern cattle fever, redwater, and by various other names. It is an infectious disease of cattle due to the presence of a protozoan blood parasite known as *Pyrosoma bigeminum*. In the United States the distribution of Texas fever corresponds generally with that of the cattle tick, with certain exceptions where the cattle tick appears to be nonvirulent The characteristic symptoms of the disease are rise of temperature, destruction of the red blood corpuscles and consequent hemoglobinuria or redwater which is due to the liberation of the blood coloring matter from the disintegrated blood corpuscles. The blood parasite is carried from one animal to another by the cattle tick, in which the parasite may live for long periods. Ticks which are attached or have been attached to cattle which are affected with Texas fever, or which have recovered from the disease, may contain the blood parasite and may, therefore, transmit the disease to healthy cattle from which they suck blood. The parasite is introduced into susceptible cattle through the puncture which the tick makes in obtaining blood. The period of incubation for this disease varies from 2 to 5 weeks, but the symptoms usually appear within 9 to 14 days. The rate of mortality is very high under ordinary conditions and medical treatment is of little avail. Recently certain experiments reported from Germany indicate that hemoglobin, or the red coloring matter of blood, may be useful in the treatment of Texas fever. The value of this treatment depends upon the obvious fact that in Texas fever the affected animals are very anemic on account of the destruction of the blood corpuscles. The use of hemoglobin, therefore, restores some of the lost coloring matter.

The quarantine line for Texas fever has been extended across the country by the Bureau of Animal Industry from Virginia to Mexico in a somewhat irregular course so that the Southern States, including a portion of southern California, lie within the Texas fever zone.

When cattle are infested with ticks during early life, they suffer from a mild form of the disease and in a large percentage of cases recover. After recovery they are immune to further attacks of the disease. This fact has been utilized in the production of artificial immunity to Texas fever. It has been found possible to inoculate young cattle with from 1 to 2 cubic centimeters of the defibrinated blood of animals which have recovered from the disease. A mild form of Texas fever is produced by this inoculation within 8 or 9 days and usually persists for 7 or 8 days. A secondary fever period may occur after about 30 days and may persist for one week. It is less serious, however. Young animals withstand inoculation better

than older ones and a larger percentage become immune. Different investigators have recommended different plans of immunization. According to recent experiments, however, it appears best to ship northern cattle south into the Texas fever area and keep them on pastures which are free from ticks until after the period of inoculation fever has passed. The advantage in this method consists in the fact that cattle do not have to be transported by railroad immediately after recovery from inoculation. The successful development of this system of vaccination has resulted in a great improvement of the dairy herds of southern States, since it is now possible to immunize pure-bred cattle for use in the Texas fever area without danger of their acquiring the disease. At present a systematic attempt is being made to eradicate the ticks.

Tuberculosis.—Of all the diseases which affect cattle, tuberculosis is the most important, not only on account of its destructiveness to cattle but also on account of the great prevalence of the disease among human beings. Tuberculosis is an infectious disease characterized chiefly by the development, in various organs and tissues of the body, of tubercles of varying size due to the action of the tubercle bacillus. The disease is generally distributed throughout the world and affects all warm-blooded animals including man. The percentage of infected animals varies in different localities and as a rule is highest in the most thickly populated districts. Among dairy herds the percentage of infection is highest in the largest herds. It may vary from zero to 100 per cent, but may be estimated at from 15 to 50 per cent, depending on the size of the herd, the care which has been exercised in forming the herd, and the sanitary condition of the premises. In Germany, infection with tubercles among cattle slaughtered in public abattoirs varies from 6 to 46 per cent and similar data have been collected in this country. On account of the general use of the tuberculin test in detecting this disease in its early stages, almost an unlimited series of data have been accumulated regarding the prevalence of tuberculosis, but the only point of value to be derived from a consideration of these data is that the disease is everywhere disseminated to an alarming and unexpected extent. In actual tests made in various parts of this country, the infection ranged from 2 to 60 per cent.

The symptoms of tuberculosis are not characteristic and may easily be overlooked until during the later stages of the disease. No help can be obtained in recognizing the disease from the general condition of the animal, since in many cases the external appearance remains excellent until within a few months before the general breakdown.

On account of the uncertainty of the symptoms of tuberculosis, it has become necessary to apply the tuberculin test for the detection of the disease. This substance is made from pure cultures of tubercle bacilli and contains the toxin without the living tubercle bacilli. When innoculated into healthy animals, it causes no disturbance, but

in tuberculous animals it causes an elevation of temperature to the extent of 2 or more degrees Fahrenheit, accompanied with swelling at the point of innoculation, trembling, and other characteristic symptoms. The great value of tuberculin lies in the fact that by its use we are able to detect the presence of tuberculosis in the earliest stages and before it would be possible to diagnose the disease from physical symptoms or by any other method.

As soon as the disease has been recognized in a herd, it is necessary to take immediate action for its control. If only one or two animals are affected and these are not especially valuable, it is perhaps best to destroy them at once and thoroughly disinfect the premises. If, however, the distribution of the disease is much greater in the herd, and particularly if the animals are very valuable, it is best to isolate all affected animals and keep them in buildings and on pastures from which healthy animals are excluded. The tuberculous cows may be used for breeding purposes for a number of years, since the disease is not inherited and their calves may be raised on the milk of other cows or on their own milk after previous sterilization. In this way considerable profit is derived from cows which otherwise would have to be destroyed.

Various investigators in Germany, France, England, and the United States have worked on a system of vaccination for tuberculosis and have succeeded in perfecting it so far that cattle may be rendered temporarily immune to the disease by the application of this method. The method consists essentially in inoculating the young susceptible animal with tubercle bacilli of human origin. It is generally known that human tubercle bacilli are less virulent than those which come from cattle and are therefore comparatively safe to use for this purpose. The method is therefore essentially the same as vaccination for smallpox. A mild form of the disease is produced and persists for some weeks, after which the animal recovers and is immune to natural or artificial infection with tuberculosis for a few months. This method has been elaborated by von Behring, Arloing, McFadyean, Pearson, and others. Quite recently Pearson has published the result of two years' experiments during which he tested this vaccination method on young animals which were already infected with tuberculosis. It was found that five or six inoculations with human tubercle bacilli of low virulence caused the tuberculous processes in the lungs and other organs to become inactive and surrounded with thick walls of connective tissue. The vaccination, therefore, appears to have a decided curative effect and may possibly be used in the treatment of the disease.

Tumors.—This term is used to denote abnormal masses of tissue of a non-inflammatory and comparatively inactive nature and located in various organs of the body. In many cases tumors arise without any obvious cause, appear to bear no relation to the nutrition of the

body, possess no physiological function, and are not easily classified from the standpoint of etiology. Different theories have prevailed regarding causes of tumors. They have been attributed to a peculiar predisposition, to mechanical or chemical irritation, to nervous influence, and to the existence of minute animal or plant parasites in the tissue. Recently many announcements have been made regarding the discoveries of the micro-organisms of cancerous and other tumors, but such discoveries require further confirmation. In general, tumors are divided into the two classes of benign and malignant growths. Benign tumors should be removed if their presence renders the animal unsightly and therefore diminishes its value. They may be readily removed by surgical methods and the operation should not ordinarily be accompanied with any serious consequence. In the case of malignant tumors, however, a cure may not be brought about by removal of the visible tumor since other foci of the disease may have already originated in other parts of the body. The treatment of malignant tumors must necessarily be left in the hands of veterinarians since successful results can not be expected from operations upon such growths by the ordinary individual.

Verminous bronchitis.—Young cattle on wet meadows or marshy pastures, especially in locations which are subject to flooding from rivers, may become infested with a small round worm known as *Strongylus micrurus.* This worm becomes lodged in the trachea and bronchial tubes which it occurs in large numbers and causes an irritation and inflammation of the respiratory membranes. In cases of serious infestation, the trachea may be obstructed so as to choke the animal and cause death. The symptoms usually include a hacking cough which may appear in the form of paroxysms. Sometimes the parasitic worm may be observed in the mucus which is expelled. In treating this disease, affected calves should be placed in a clean, dry stable and subjected to fumigation with chlorin gas or sulphur fumes. The inhalation of these irritating gases causes violent coughing, as a result of which the worms may be expelled. Calves may also be treated by inserting a hypodermic syringe between the rings of the windpipe and injecting into the trachea a mixture of equal parts of turpentine and sweet oil to which a few drops of carbolic acid have been added. A mixture of olive oil and turpentine may also be used for the same trouble. In some infestations with this worm, however, numerous lines of treatment have been tried without any apparent success. Wherever the disease appears, it is desirable that calves be removed from low, marshy pastures in which the disease occurred and should be provided with better feed and clean water in troughs.

Warble fly.—This insect was at first confused with the European species but should really be referred to as *Hypoderma lineata.* The adult is a black fly thickly covered with yellowish hairs and about ½ in. in length; there are two yellow and white bands on the body.

The eggs are laid on the back of cattle after which they gain entrance to the alimentary tract on account of the cattle licking themselves. The larvæ then hatch out and make their way through the walls of the esophagus and finally into the subcutaneous tissue along the back of the animal. This migration occupies several months. Immediately under the skin of the animal the larvæ pass through several stages of growth finally attaining considerable size. Upon reaching full size the maggot emerges from the skin and falls on the ground where it remains until the adult fly issues. The chief injury from this pest is done to the skin of the animal and in this respect the loss is considerable. In preventing the attacks of the warble fly the backs of cattle may be smeared with fish oil or kerosene.

Wounds.—In cattle wounds seldom receive the attention which they deserve. While small wounds such as abrasions of the skin may not lead to serious consequences under favorable conditions they are always susceptible to infection with comparatively nonvirulent bacteria or to infestation with fly larvæ. In such cases the wounds cause great irritation, loss of flesh, and diminution of milk yield. The possibility is always present, moreover, of infection of wounds with the organisms of tetanus or septicemia. It is highly desirable, therefore, that all wounds of the skin be immediately treated with a suitable antiseptic solution such as carbolic acid, corrosive sublimate, formalin, sulphate of zinc, blue vitriol, or nitrate of silver. In warm seasons it may be desirable to rub some repellent ointment upon such wounds in order to prevent flies from depositing their eggs.

CHAPTER IV.

FEEDING DAIRY COWS.

A few years ago a knowledge of the principles and practice of feeding cows would not have been considered among the educational requirements of the milk inspector. Now however the inspector is almost always asked for suggestions regarding feeding. The dairyman recognizes that feeding is the most important part of his business. The cow is properly looked upon as a machine for the transformation of feeds into milk. The regularity and continuance of the milk flow, and the quantity and quality of the milk depend upon the kinds and relative proportions of feeding stuffs in the ration. The dairyman's chief objective point is the production of the largest possible milk yield. To this end it is a duty of the milk inspector to give all possible assistance, for the milk producer's profits are none too large, and the inspector can suggest the improvement of sanitary conditions with better grace if he can also give some helpful advice. The following brief discussion of feeding cows is intended to be of help in the production of large quantities of standard milk.

During the whole period of lactation the dairy cow should receive grain, succulent feed and dry roughage. No cow can be kept at her highest productive point without feeding liberal quantities of grain. The effectiveness and palatability of any ration of grain and roughage are increased by adding succulent feed. The comfortable feeling which induces restfulness and rumination on the part of the cow comes from a full stomach, which is achieved by feeding suitable roughage.

Grains for Cows.

The most widely used and best grain feeds for milk production are bran, wheat, middlings, barley, brewers' grains, malt sprouts, buckwheat bran and middlings, corn and its products (corn meal, gluten meal, feed, gluten flour, sugar feed, etc.), cottonseed meal, kafir corn, linseed meal, oats, peas, and spelt.

Bran may be fed in rations of 2-6 or more pounds per day. It is highly palatable has a favorable effect upon digestion, and tends to the production of a high quality of milk. The milk consumer can have no objection to its use to the full capacity of the cow. Bran is somewhat less effective than cottonseed meal. It may well be fed in combination with wheat middlings or corn meal.

The best barley byproducts are barley sprouts and brewers' grains. Malt sprouts should be fed wet, and may constitute one third of the grain ration. They are equal in effectiveness to a mixture of oats and peas but slightly inferior to cottonseed meal. About 2 pounds daily is a suitable amount. Brewers' grains at the usual price are an eco-

nomical feed in rations of 10-15 pounds per day with corn meal. A good ration of dried brewers' grains is 2-5 pounds. Some dealers have raised objection to the use of brewers' grains on the ground that they injure the flavor of the milk, but as a rule no bad effect is noted.

Buckwheat middlings are more effective than bran and corn meal, produce a firm butter, and milk of an excellent flavor. They may be mixed with other grains to the extent of 3 or 4 pounds per day. They are not always well relished when fed alone.

Corn meal is more effective than whole corn but should not be fed alone. Better results are obtained by mixing it with a more nitrogenous concentrate such as bran, cottonseed meal or linseed meal. Corn meal may also be balanced by mixing with gluten meal or gluten feed. These latter produce milk of a good flavor but have a tendency to soften the butter fat. About 2 pounds per day is enough of either.

Cotton seed meal is perhaps the most effective milk producer of all the grain feeds. It should be fed with caution, beginning with 1/4 lb. per day and gradually increasing to 4-6 pounds. Cotton seed meal always hardens the butter fat but may give it a light color. It is easily balanced by mixing it with corn meal. When thus fed it always increases the milk flow.

Distillers' grains are not very palatable and are objected to on account of the flavor of the milk.

Kafir corn and kafir corn meal are about equal to corn and corn meal in every respect. The quality of the butter is sometimes not quite equal to that from corn meal.

Linseed meal is an excellent laxative and its beneficial effects are seen in the glossy coat of the cows. It increases the milk flow and favorably affects the quality of the milk and butter. It may be fed in rations of 6 pounds but the best results follow the addition of 1 pound to an 8-pound ration of mixed bran and corn meal.

Narrow and Wide Rations.

Narrow and wide rations are short convenient terms used to denote the fact that the ratio of digestible protein to other digestible matter in the ration is wide or narrow. The figures taken in calculating nutritive ratios are based upon the heat value of the various constituents of the ration. The heat value of fats is 2.4 times that of carbohydrates. In calculating the nutritive ratio of a given ration the amount of digestible fat multiplied by 2.4 is added to the digestible carbohydrates and the sum divided by the amount of digestible protein. The quotient is the nutritive ratio. The nutritive ratio of timothy hay is 1:15.5 and is called wide, while the nutritive ratio of linseed meal is 1:1.7 and is called narrow. If the dairyman wishes to compute the nutritive ratio of various combinations of feeds he should have a table of analyses showing the percentage composition of feeding stuffs. Such a table is given in U. S. Dept. Agric. Farmers' Bul. 22, which may be had for the asking.

It is evident from the above statement that narrow rations contain relatively more protein. The protein or nitrogenous matter in the ration is the most costly of all the constituents. Narrow rations are, therefore expensive. The practical point for the dairyman is to determine whether it pays to feed narrow rations. The necessary protein for the ration may be obtained by purchasing or raising bran, cottonseed meal, linseed meal, wheat middlings, gluten meal, oats, peas, etc., or by the more extensive use of leguminous crops such as clover, alfalfa, field peas, cowpeas, soy-beans, vetches, etc. With ordinary roughage and succulent feeds corn meal would make a wide ration. Such a ration may be balanced or made narrower by adding some of the nitrogenous feeds just mentioned. If all the nitrogenous feeds have to be purchased at ordinary market prices it will not pay to make the ration too narrow. If on the other hand the protein in the ration is obtained from legumes grown on the premises a narrow ration may be prepared very cheaply.

Narrow or medium rations are superior to wide rations for milk production. Wherever the experiment has been tried of narrowing the ration for cows which have previously received a wide ration, the result has been an increase in milk production. As a rule the increase more than counterbalances the extra cost of the ration.

Size of the Grain Ration.

The amount of grain fed daily to cows ranges from 2 to 15 pounds. The quantity of grain to be fed is by no means an indifferent matter. Only the best cows can profitably utilize the largest grain rations. For the average cow 8 pounds of grain should be the maximum. In fact, it requires a good cow to give profitable returns from 8 pounds of grain daily. This is largely an individual matter with each cow. If all grain feeds have to be purchased and the market price is high there is economy in reducing the grain ration. If on the other hand grains are cheap or are largely raised on the farm the grain ration should be put at the highest point of economic return. If a cow is receiving 2 pounds of grain and the grain ration is increased by 2 pounds there is sure to be an increase in milk production. Likewise a diminution in a moderate grain ration will result in reducing the milk yield. For good dairy herds 6-8 pounds of mixed grains constitute a suitable ration.

Succulent Feeds.

A suitable amount of succulence in the ration may be obtained by the use of pasture, soiling crops, silage or roots. Pasture in good condition has the great advantage of furnishing green feed in the tender and most palatable stage. In grazing, cows get healthy exercise in the open air. Pasture has the further advantage of being the cheapest and easiest way to provide green feed. The disadvantages of pasture are worry from flies, garlic and other weeds which spoil the

flavor of the milk, shortage of grass from drouth, and exposure of cows to heat. The best pastures are those which are sown with cultivated grasses.

Soiling.—The soiling system has taken the place of pasture where land values are high. In this system the farm is divided into small fields which are planted to various forage crops so as to secure a succession of green forage from May to November in the North and nearly the year around in the South. A system of rotation must be adopted, for most crops are at their best for only about 10 days. The best crops for soiling are alfalfa, red clover, crimson clover, cowpeas, field peas, soy-beans, corn, oats, rye, millet, kafir corn, sorghum, rape, teosinte, mixed grasses etc. While each crop is in its prime enough is cut for each feeding, hauled at once, and fed in a fresh state to the cows in the stable or in the yard. From three to five times as much forage is obtained by soiling from an acre of land as by pasturage. Less land is therefore required for a given number of cows. Soiling will impoverish the land if legumes are not sown at frequent intervals in the rotation. Legumes are the most valuable soiling crops, but corn, sorghum, teosinte, rye, and mixed grasses are very palatable and easily digested. There is considerable labor involved in operating a system of soiling. Rape is somewhat objectionable, for it may taint the milk. In estimating the necessary acreage of crops it may be expected that an acre of clover will carry 10 cows for 16 days, an acre of corn for the same length of time, an acre of cowpeas for 21 days and an acre of sorghum for 36 days. A cow will eat 40-60 pounds of green feed per day in addition to grain and hay.

Silage.—Silage is fermented corn or other forage preserved in air tight structures known as silos. Silage ordinarily means the fermented corn plant (ears and stalks). Other plants are used for silage, such as clovers, alfalfa, sunflowers, sorghum, cowpeas, sugar beets etc. They may be ensiled alone or in combination with corn. Crops for silage may be harvested in rainy weather when it would be impossible to make hay. The chief advantages of silage are that the whole crop may be harvested at the time when it has attained its greatest weight of digestible matter, that the work of harvesting is less than by the soiling system or dry curing, and that it provides a supply of succulent feed in winter. It does not taint the flavor of the milk if fed after milking. The proper ration of silage is 30-35 pounds per day.

Roots and fruits.—Succulence and palatability may also be added to the ration by the use of roots and fruits. Cull apples may be fed in rations of 15-35 pounds per day. Apple pomace, fresh or ensiled, has a favorable effect upon the quality of the milk. Artichokes and field beets are about equal to corn silage in milk production, but rather more expensive. No objection can be raised to carrots, but cabbage and mangels may have an undesirable influence upon the flavor of the milk, and the quality of the butter. Potatoes are inferior to corn silage but

have no specific bad effect upon the milk. Pumpkins may be fed to the extent of 40 pounds per day with good results. Turnips are an inferior root for cows and affect the odor of the milk. Sugar beet pulp is an excellent dairy feed. It may be fed in rations of 20-70 pounds per day in addition to 6 pounds of hay and 6 pounds of grain. Milk from cows fed sugar beets or sugar beet pulp is of good flavor.

Dry Roughage.

The chief hay and other roughage crops for cows are alfalfa, clovers, cowpea, field pea, vetch, soy-bean, brome grass, corn, kafir corn, millet, oats, rye, sorghum and timothy.

Alfalfa is highly nitrogenous and a very effective milk producer. It may be fed in rations of 20-40 pounds per day but about 15-30 pounds is a better ration. A combination of alfalfa and corn meal is one of the cheapest rations which can be devised for dairy cows. By furnishing protein in the form of alfalfa or other legumes in place of purchased nitrogenous grain feeds a saving of 30 per cent is made in the cost of milk production. Milk and butter from alfalfa are of excellent quality. The only objection to alfalfa is its tendency to produce bloat, but cows may become accustomed to it so that no serious consequences result.

Brome grass may be used to replace timothy or other hays. It is about equally valuable with timothy. It is not raised in large quantities. There is no objection to its use. Clovers are worth about $15-$17 per ton for milk production. Red, crimson and alsike clovers are about equally valuable, and may be economically used to replace nitrogenous grain feeds. Moldy clover hay is objectionable, otherwise clover is an excellent dairy feed.

Corn stover is not as highly appreciated as it should be. If run through a cutter or shredder nearly all of it will be eaten by the cows. It is fully equal to the best timothy hay for cows. Corn fodder is equal to silage in digestible matter and about equally palatable. Well cured stover is an unobjectionable feed, and it seems strange that so much of it is allowed to go to waste in the corn belt.

Cowpea hay is an extremely stimulating feed. It is coming more and more into prominence, and produces a good quality of milk. Soule found that with cowpea hay and cottonseed meal milk can be produced for 5 cents a gallon and butter for 10 cents a pound. In other experiments in Alabama cowpea hay showed a feeding value equal to that of bran.

Salt marsh hay may taint the milk, and is not a very effective feed. Kafir corn, fodder, lespedeza hay, millet hay, oat hay, serradella, timothy, vetch hay, wheat hay, and soy-bean hay may be fed to cows before or after milking without affecting unfavorably the quality of the milk. Soy-bean hay is a particularly effective milk producer. In rations of about 7 pounds in combination with cottonseed meal and wheat bran it greatly stimulates the milk flow.

Miscellaneous Feeds.

From the feeding stuffs mentioned above suitable rations may be made up for dairy cows in any locality. Occasionally other miscellaneous feeding stuffs are recommended for dairy cows.

Proprietary feeds.—Farm papers and other periodicals continuously carry advertisements of various proprietary feeds. The manufacturers claim that these feeds will increase the weight of the animal and also the milk yield, while improving the health of the cow. The numerous chemical analyses which have been made of these substances have shown conclusively that they contain well known chemicals and drugs which may be purchased at any drug store at a much lower price. The prices charged for proprietary feeds are exorbitant considering their slight medicinal and nutritive value. If cows are fed well balanced rations of wholesome feeds, and if the rations are varied from time to time with proper regard to their relative proportions, the cows will not need condimental feeds. If loss of appetite, lack of condition, or disease arise, the matter should be investigated, a change made in the ration or proper medicines administered.

Other feeds.—Dried molasses beet pulp may be fed in rations of 3 pounds to replace an equal amount of bran. No sanitary objection can be raised to it. Its feeding value is about $12 per ton. Feeding small quantities of bone meal to cows has the effect of slightly increasing the amount of phosphoric acid in the milk ash. If there is no other use for skim milk it may be fed to cows with good results. Cows may be fed sugar without harm but there is no economy in the process.

Salt.—A supply of a good quality of salt should be constantly accessible to the cows. It may be given in the form of a granulated salt or in large chunks for licking. If salt is withheld the milk falls off perceptibly.

Water.—Reference has been made to the water supply for cows in Chapter III. A constant supply should be provided, moderately cool in summer, and not ice-cold in winter. The quality of drinking water for cows should be as good as that used for household purposes.

Sample Rations.

The possible combinations of suitable feed stuffs into good rations for cows is almost unlimited. Perhaps the best compilation of actual rations used by dairymen in different parts of the country is that published by Woll in Bulletin 38 of the Wisconsin Experiment Station. This list contains 100 rations adapted for use particularly in the eastern, northern and western States. The following rations have been suggested for use in Oklahoma, Mississippi and other southern States.

Ration 1.—Johnson grass hay, 13 pounds; cottonseed hulls, 15 pounds; cottonseed meal, 3 pounds; wheat bran, 4 pounds.

Ration 2.—Cowpea hay, 15 pounds; corn silage, 40 pounds; wheat bran, 5 pounds.

Ration 3.—Cottonseed hulls, 20 pounds; cottonseed meal, 4 pounds; wheat bran, 5 pounds.

Ration 4.—Cowpea hay, 10 pounds; cottonseed hulls, 15 pounds; cottonseed meal, 3 pounds.

Ration 5.—Cowpea hay, 10 pounds; bermuda grass hay, 10 pounds; wheat bran, 3 pounds; cottonseed, 6 pounds.

Ration 6.—Bermuda grass hay, 18 pounds; cottonseed meal, 2 pounds; wheat bran, 3 pounds; corn and cob meal, 3 pounds.

Ration 7.—Cowpea hay, 15 pounds; cotton seed, 8 pounds; corn meal, 6 pounds.

Ration 8.—Sorghum hay, 20 pounds; cowpea hay, 10 pounds; cottonseed meal, 3 pounds.

Ration 9.—Alfalfa, 15 pounds; cottonseed hulls, 12 pounds; cottonseed meal, 3 pounds.

Ration 10.—Crab grass hay, 15 pounds; cowpea hay, 12 pounds; cotton seed, 6 pounds.

Ration for cows giving eleven pounds of milk per day:

No. 1. Cottonseed, 9 lbs.; corn stover, 20 lbs.

No. 2. Cottonseed, 4 lbs.; cottonseed meal, 1 lb.; corn meal, 3 lbs.; prairie hay 10 lbs.; corn stover, 10 lbs.

No. 3. Cottonseed 6 lbs.; alfalfa hay, 16 lbs.

No. 4. Cottonseed meal, 2 lbs.; corn meal, 4 lbs.; prairie hay, 15 lbs.

Rations for cows giving sixteen and one-half pounds of milk per day:

No. 5. Cottonseed,9 lbs.; prairie hay, 20 lbs.

No. 6. Cottonseed, 9 lbs.; alfalfa hay, 16 lbs.

Rations for cows giving twenty-two pounds of milk per day:

No. 7. Cottonseed meal, 3 lbs.; corn meal, 10 lbs.; prairie hay, 16 lbs.

No. 8. Cottonseed, 6 lbs.; cottonseed meal, 2 lbs.; corn meal 5 lbs.; prairie hay, 15 lbs.

Rations for cows giving twenty-seven pounds of milk per day:

No. 9. Cottonseed, 3 lbs.; cottonseed meal, 4 lbs.; corn meal, 10 lbs.; prairie hay, 10 lbs.; corn stover, 10 lbs."

The kinds of green forage chiefly used in Hawaii are Para grass (Panicum molle), alfalfa, sorghum, cane tops, jack beans, cowpeas, vines of sweet potato, honohono (Commelina nudiflora), banana butts, leaves of ti (Cordyline terminalis), corn stalks etc. In the dairy section of Glenwood, where the rainfall is more than 300 inches a year, honohono is perhaps giving better success than any other green feed. At Glenwood honohono appears not to carry the immature stages of the fluke worm as in many other localities. Recently the beginning cotton industry has added cotton seed to the possible grain feeds for the Hawaiian dairyman. Corn is also being produced in increasing quantities. Our most important home-grown grain feed, however, is the algaroba bean. This may be purchased for about $7.50 per ton, unground, and is worth much more as compared with the price of other grains. It is fed in rations of 3 to 6 pounds per day.

CHAPTER V.

BUILDINGS AND PREMISES.

Dairying is a special line of animal industry in which the sanitary requirements are much more severe than in other related lines. These requirements do not begin merely with the product but extend also to the cows, the stables and the whole surrounding premises. The business fits in well with other branches of farming and as a rule some other line is carried on simultaneously in order to utilize most profitably all the products of the farm and the byproducts of the dairy. Business and sanitary considerations in dairying, however, are not always identical. Hogs and chickens give excellent returns for the byproducts of the dairy but no other animals should be kept in the same stable with cows. Such buildings must be separated from the dairy barn.

Stables.

It obviously lies outside the purpose of the present volume to enter into the structural details and architectural consideration of dairy buildings. The only standpoint from which we can discuss these matters is that of sanitation. In any thorough system of inspection the milk inspector must visit the producer from time to time and pass upon the general conditions which he finds there. In order that this inspection may proceed without friction and accomplish the intended results it is desirable that the dairyman and inspector should look at the problem from as near the same viewpoint as possible. The inspector will then better appreciate the farmer's difficulties and the farmer will get a clearer idea of what is involved in the production of clean milk.

The first consideration in the construction of a stable for dairy cows should be the cleanliness and ease of cleaning. The stable should be so located as to permit of thorough drainage and thus prevent undue dampness. It should preferably face the east and south or at least the windows should be chiefly on these sides in order to admit a maximum amount of sunshine at all times, and heat in winter. If the location of the stable admits of providing it with a supply of good running water, so much the better.

The only satisfactory material for the floor of a cow stable is cement. Wood rots and absorbs odors. Brick and stone allow the accumulation of filth between one another. Cement concrete is the most durable of all materials for floors, is without odors, may be laid smooth enough to be easily cleaned without being too slippery for the cows to walk upon, and is impervious to water. It may therefore be cleaned at intervals by flushing with water.

The platform on which the cows stand should be $4\frac{1}{2}$-5 feet wide, depending on the size of the cows. The width should be such that the cows do not have to stand with their hind feet in the gutter. A gentle and uniform slope of the platform toward the gutter brings about a satisfactory drainage. The manure gutter may be 14-16 inches wide, 8 inches deep on the side next to the cows and 6 inches on the opposite side. The space allowed for each cow varies among dairymen from 3 to 4 feet. A space of three feet is rather narrow unless the cows are small. If the cows are gentle no partition between them is required. There is an advantage in an iron bar, however, in that the cows are thereby prevented from turning sideways and soiling the bedding and the other cows. The simpler the partition the better, for it is easier to clean. Similarly with mangers, if they are of too complex construction they are difficult to clean and food is often left in the corners to sour. It is really not necessary to have mangers and many dairymen prefer to build their stables without them. If mangers are used they should have rounded corners and no crevices to hold dirt. A slight concavity in the cement in front of each cow with an opening in the center for flushing out serves the purpose of a manger. If the cows are dehorned and gentle as they should be there is no need of partition between their heads. The feeder is supposed to be present when the cows are eating so as to prevent them from stealing one another's feed.

In some stables, in place of the usual manure gutter, there is merely a drop of eight inches behind the cows and the concrete slopes gently upward to the wall of the stable. The advantage claimed for this method of construction is that the manure is more easily removed and the whole readily flushed. The slope should not be steep, otherwise the cement will be slippery for the cows. The floor should meet the wall in a concave turn and without a sharp corner.

The modern cow stable is a long structure designed for accommodating two rows of cows. Whether or not the rows of cows should face each other or the outside wall is a matter for each dairyman to determine. From a sanitary standpoint there is little or no preference. In one case the feeding passage is through the center of the stable and the manure is removed by two passages along the walls of the stable. In the other case the manure passage is in the center and the cows are fed by two passages next to the walls. The relative advantages of these two methods will appeal differently to different dairymen. If the soiling system of feeding is adopted it is convenient to have a driveway through the center of the stable so that the green feed may be thrown in front of the cows directly from the wagon. According to the alternative scheme of construction there would be only one manure passage and the manure could be loaded directly into the wagon. In such a stable, if of great length, the feed can best be delivered to the cows from bucket carriers running on an overhead track. This track may connect with the silo at the end of the stable. The manure may

be removed by wheelbarrow or by bucket carriers and dumped into a manure pit outside of the stable or into the wagon to be hauled away daily or every other day.

An outside width of 36 feet is sufficient for a stable to accommodate two rows of cows. The length will of course vary according to the number of cows. The strictly sanitary stable is not supposed to be used for any other purpose than as a permanent or temporary restraint for the cows. Some dairymen use one stable merely for milking. In this the construction may be cheap except the cement floor. The chief advantage of separate milking stables is that they may be kept well ventilated so that the odors of cows and manure are present only to a minimum extent. If stables are to be used for the permanent housing of the cows, they must be cleaned frequently. They are supposed to be only one story high and since they are not to be used for containing hay or other feed the dust problem is largely eliminated. The milk room is supposed to be separate from the stable and to be used for no other purpose. This is to avoid the absorption of odors by the milk.

If the ceiling is 9 feet high this will give ample air space for the cows. The ventilation of stables is a matter about which the greatest difference of opinion has prevailed. The question is by no means settled and cannot be considered at length in this connection. We are interested in ventilation in this discussion only so far as it affects the odors of the stable and the health of the cows. Obviously the more rapid the change of air in a stable the less disagreeable will be the odors. For this purpose it is better that the foul air be removed from near the floor rather than from the ceiling. The products of respiration and animal metabolism are near the floor, while the warm air is at the ceiling. If, therefore, fresh air is let in high up on all sides of the stable and foul air is discharged from near the floor, the odors and respiratory products will be removed with a minimum loss of warmth. No system of artificial ventilation will operate unless the stable is constructed tightly and the currents are controlled. If the air leaks in freely around the doors and windows it will obviously interfere with the intended movement of air in the ventilation shafts. Since a loosely constructed stable needs no artificial ventilation and since an artificial system is of no value except in a practically air-tight stable the question has been raised by many dairymen how much attention should be given to the matter of ventilation.

In summer the ventilation of any stable is a simple matter. In winter, however, there is the question of heat to consider. Here again we have a wide divergence of views. On the one hand it is advocated that the temperature of the stable even in the coldest weather should not fall blow 50-60°F. If this temperature is maintained without artificial heat it is necessary that the change of air be so regulated that the animal heat of the cows will keep the air of the stable at the desired temperature. Theoretically there seems to be no objection to this plan, but if cows are kept according to it they become very susceptible

to cold and are likely to suffer if for any reason they have to be turned outdoor in winter.

The whole question of the optimum temperature for cows is in controversy and nothing would be gained therefore in attempting to settle the matter at this time. Professor Fraser at the Illinois Experiment Station investigated the problem thoroughly and came to the conclusion that cows do well in open covered sheds even in the coldest weather of winter. Keeping cows in a stable continually and under approved sanitary conditions involves a great deal of work and careful attention to each individual cow. Those dairymen who allow their cows the freedom of a shed or covered barnyard and use the stable only for milking are well pleased with the system. In reply to a circular letter sent to them by Prof. Fraser they stated in essential uniformity that the method saves labor in cleaning the stable and in feeding roughage, keeps the cows more comfortable and preserves the manure in better condition by reason of the greater amount of bedding used. One dairyman reports that "the system is good only where straw is abundant that can be so utilized. If the straw is limited in amount the system would be filthy and if the herdsman is negligent or careless the cows will become more or less filthy. With a careful man and a reasonable attention the system works exceedingly well." Another farmer states "our cattle are cleaner than any herd of stalled cattle I ever saw. A soiled cow is a rare sight in our herd. By this method we have increased milk yield and greater healthfulness; have not had a case of milk fever since our dairy started."

The excellent reports made on this system by various dairymen led Prof. Fraser to test the scheme at the University dairy. A shed 30x68 feet afforded abundant room for 22 cows which were very satisfactorily cared for in this manner. From the test the following conclusion was drawn: "It has been found that the cows keep much cleaner than when stabled and that the milking stable is in a much more sanitary condition, consequently it is easier to produce clean milk. By this method there is less difficulty in providing cows with an abundance of fresh air and they are more vigorous and healthy and have better appetites than when kept in a stable. Since they can move about and get exercise they will not suffer in cold weather if the temperature is somewhat lower than in the ordinary stable." The great saving in labor and in fertility of the manure is enough to highly recommend this method so long as there are no sanitary objections. The increasing complexity of inspection systems puts increasing burdens on the dairyman and raises the price of milk. The limit will soon be reached beyond which the ordinary milk consumer can not go. Any sanitary system, therefore, which at the same time reduces the cost of production must be looked upon with favor.

As already indicated the approved sanitary stable is only one story high and used for no other purpose than milking. Some large city milk dealers will not accept milk unless these conditions are complied

with. These requirements are made, however, on the assumption that the farmer will not exercise any care in overcoming the insanitary conditions of his farm. This is true of some farmers but not of all. In all systems of sanitary improvement and reform the best and most reliable results are obtained only when the men concerned are induced to take a direct and personal interest in the matter. It must be admitted that there are dairymen who produce milk of excellent quality under conditions which would yield doubtful results in the hands of a careless man.

The vast majority of dairy stables throughout the country are built in connection with a cow barn which is also used for the storage of feed. A favorite type of such barns has the cow stable in a basement. Clean milk can be produced in these stables provided the walls and ceiling are tight, the floor impervious to water, the feed delivered to the cows without raising a dust and the stable cleaned in a satisfactory manner. Many, at present, highly insanitary dairy stables could be immensely improved and rendered passable by putting in more windows, a cement floor and whitewashing the walls and ceiling. It is unnecessary to discuss this point further. The intelligent dairyman knows the stable conditions which allow the production of clean milk. In the interest of the public the milk inspector has the right and duty to insist upon these conditions being met by the dairyman. Unreasonable requirements in stable construction should and will not be made, but the dairyman who wishes to continue in the business at a profit may as well meet the reasonable demands of the milk-consuming public as promptly as possible. Clean milk can not be produced in dark stables, on a moist poorly drained foundation, with rotten manure-soaked wooden floors. All such conditions can be readily remedied by the intelligent dairyman, and no other kind of a dairyman has the right to furnish milk to the public.

Bedding.

The choice of bedding is a matter of considerable importance to dairy farmers. A good bedding material should be easily distributed, keep the cows comfortable, remain in place, absorb the liquid manure, and should add no dust to the stable. Perhaps the most thorough comparative test of the value of different substances for bedding has been made by Professor Doane. A comparison was made between cut and uncut wheat straw, cut corn stover, sawdust and shavings. When cows were kept in the stable 16 hours per day it required 2.3 lbs of whole straw and 2.9 pounds of cut straw daily per cow to keep them clean and make them comfortable. Cut straw was too easily kicked about, became unevenly distributed on the floor and packed down too solidly for comfort. Whole straw proved superior to cut straw and under the conditions named only 1800 lbs. were required per year per cow as compared with 2300 lbs. of the cut stray. Stover cut with a silage cutter also compared unfavorably with whole straw,

3.2 lbs. daily being required per cow. Except in the amount required, however, it proved to be a better bedding than straw. It kept the cows cleaner and staid in place better. It may well replace wheat straw for bedding to a large extent. Sawdust and shavings were found to be ideal materials for bedding. They are as nearly dustless as any bedding can be, keep the cows exceedingly clean and make the manure easy to spread. Nothing can compare with sawdust or shavings in giving a cleanly appearance to the stable. Sawdust can not be conveniently obtained except in the vicinity of sawmills, but in such localities it is the cheapest bedding. In Doane's test the annual cost of bedding per cow stabled 24 hours per day ranged from 45 cents on sawdust to $4.82 on cut wheat straw.

Barnyards.

The yards about the stable need intelligent care to prevent them from becoming filthy and unsanitary. If the soil in the barnyard is not unusually well drained it is sure to be muddy especially in the spring. This may be largely obviated by a covering of gravel or cinders, or still better by paving with brick. If the last method is adopted the yard is easily cleaned. The improvement of conditions about barnyards is often objected to on the ground of the expense involved in the undertaking. It is a necessary expense, however, on every approved dairy farm. Without dry well drained yards it is impossible to keep the cows clean. The covered sheds referred to above are a part of the yard and must be plentifully supplied with bedding. The more bedding the more completely is the liquid manure absorbed and the less work in cleaning the cows. Yards from which the manure is removed only once per year are unspeakably filthy and cause a great amount of extra work in cleaning the cows. Furthermore the fertility of the manure is in great part lost.

Disposal of Sewage.

One of the most important points in the sanitation of every dairy farm is the method of disposal of sewage. The stable may be thoroughly cleaned, the cows carefully groomed, the feed stuffs above criticism and the milk utensils in approved condition, and yet the manner of disposing of sewage may be such as to make it impossible for the inspector to approve the premises as a whole. One of the greatest dangers in this connection is that the water supply may become contaminated. If such is the case all other sanitary precautions come to naught. Water used in washing milk utensils must be above suspicion. Some of the worst outbreaks of typhoid fever ever reported were traced directly to contaminated water used in cleaning the milk vessels. Moreover there must be a clean supply for the household and for the cows. In order to secure this the water must be protected so that no sewage comes in contact with it by seepage through the soil.

Many systems of sewage disposal have been proposed and one of the best is that suggested by Prof. Erf of the Kansas Experiment

Station. This system is designed to take care of the sewage from the house, stable and milk room. The manure gutter in the stable, the waste pipe from the milk room and the kitchen and closet in the house are all connected by means of sewer pipe with a septic tank, conveniently located to receive all this drainage. If the slope of the ground will permit it is best that the tank be placed below the level of the soil to avoid freezing in winter. Otherwise it must be covered for protection. The septic tank should have two to four compartments so as to insure the thorough liquefaction and dissolution of all waste material. This decomposition is brought about by the action of bacteria and results in a fluid sewage from which the disagreeable odors have been largely removed. The process of decomposition is greatly furthered by the presence of large quantities of water. On dairy farms an abundance of water is used in washing the milk utensils and in flushing the stable.

In the sytem proposed by Prof. Erf the septic tank daily receives liquid manure and other forms of fluid sewage. An outlet must therefore be supplied for the sewage to be discharged from the tank after thorough liquefaction. The sewage is to be distributed on the neighboring parts of the farm either by surface irrigation or by a system of sub-irrigation pipes. Since there will be a constant discharge of liquid sewage it is necessary that in winter it be carried in pipes below the line of frost. For this purpose the ordinary porous tile is used. A main line of four-inch tile and laterals of three-inch tile will carry the sewage. It is suggested that one portion of the farm receive the sewage in summer and another in winter. The tile for use in summer need not be laid deeper than 8 inches in the ground.

By this sytem the soil is fertilized and irrigated at the same time. If the soil thus treated be devoted to intensive farming or market gardening, the annual increase in productiveness will pay the total cost of installing the sewage plant. The tank should be constructed of brick or concrete, and for the ordinary farm a tank 10 feet square and four feet deep will be sufficiently large.

The disposal of farm sewage by the method just described should eliminate nearly all danger of pollution of the well water. Nevertheless some additional thought must be given to this matter. It is generally known that water which filters through several feet of soil is practically free from contamination. The well must therefore be so constructed that no impurities can gain entrance to it either from the top or the sides. This may be accomplished by making the wall water-tight down to the level of the water.

Milk Rooms.

In the plan proposed by Pearson for the improvement of market milk the following suggestions are made regarding milk rooms: "There shall be a room which shall be used for no other purpose than to provide a place for handling the milk, storing clean milk utensils, and

holding fresh milk previous to its removal from the dairy. It shall be within easy access of the stable, but so placed that it can not easily be reached by dust or odors from the stable or yard or other sources. If under the same roof with the stable it shall be separated therefrom by a light, clean and ventilated room or passageway at least 4 feet wide and 4 feet long with doors kept closed by springs. Or the arrangement shall be such that it shall be necessary to pass out-of-doors in going from the stable to the milk room.

This room shall be entered only by persons having business therein; no one shall be admitted who has been where a contagious disease exists or who is wearing dirty garments. It shall be kept scrupulously clean and shall be occasionally thoroughly dried in all its parts. It shall contain nothing that is not required for handling milk. Dairy utensils shall be removed to another room for cleaning as soon as they have been used. Sour milk shall not be left in the milk room. It shall be well lighted. Windows and doors shall be fitted with screens to keep out insects. It shall have a hard floor, impervious to moisture. The drain shall be provided with a common S-trap, and so constructed that it can be easily cleaned by steam or disinfectants. Except under unusual conditions the drain shall be at least 200 feet long. No permanently moist place, except running water, shall be allowed in its vicinity. The walls and ceiling shall be kept clean and light colored. If whitewash is used, a fresh coat shall be applied at least every three months, or oftener if necessary, to keep the walls clean. Spots of mold shall not be allowed to develop on the walls. If there are shelves of wood in the room, they shall be painted or oiled. No accumulation of dirt, cobwebs, rubbish, or unclean materials shall be permitted."

Not every dairy farmer will have an ideal milk house. It is not necessary that it be an elaborate or expensive structure, for satisfactory cleanliness may often be brought about in an economic manner. The milk house may be built over a natural spring and the dairyman may depend upon the spring water for cooling the milk. In other cases the milk room may be attached to the stable or the dwelling house, or may be a separate building with ice house attached. The only essential point is that it be so constructed as to admit of easy and thorough cleaning. No other operations should be allowed in the milk room which might in any way contaminate the milk. In other words the milk room is maintained for the purpose of mixing, straining, aerating, cooling and storing the milk. It may be constructed of wood but the floor should be concrete.

In connection with the milk room there should be a wash room in which all dairy utensils are to be cleaned. It should be provided with hot and cold water and steam, if possible. The shelves on which the utensils are set to dry should be before windows admitting an abundance of light. On the vast majority of farms the milk utensils are washed by farmers' wives and set on outside shelves to dry in the direct sunlight. This method is fairly satisfactory except on dry

windy days when the air carries considerable dust. Milk utensils sitting out to dry are familiar sights on dairy farms, but special wash rooms are to be preferred from a sanitary standpoint and in the long run are cheaper and save much drudgery to the women folk of the farm.

Inspection of Buildings and Premises.

The inspection of dairy premises is one of the most important parts of any official system for safeguarding the health of the milk-consuming public. It is at the farm that most opportunity is offered for the contamination of milk. The cows may become diseased, the stable foul and insanitary, the milkers affected with a contagious disease or in contact with such a disease, or the method of sewage disposal may be entirely at fault and the water become polluted. Moldy or otherwise unhealthy feed may render the milk secretion abnormal, and finally carelessness in handling the milk may enormously increase its dirt anl bacterial content.

The inspection of the dairy herd and premises should be made by a competent veterinarian with some knowledge of sanitary engineering. Such an inspector is prepared to recognize and deal promptly with any diseases which may be present in the herd. The tuberculin test should be applied at not longer intervals than six months, in fact the progressive dairyman insists upon this precaution as a means of self protection. The milk of tuberculous cows can not be safely used as food for man or animals without previous sterilization. Tuberculous cows must be at once separated from the rest of the herd and never allowed to come in contact with them again. There are also a number of diseases which temporarily render the milk unfit for use. In this list all forms of mammitis or garget stand at the head. In cases of inflammation of the udder the milk becomes abnormal, contains exudations sometimes of a hemorrhagic nature, and pus, and in some instances may carry pathogenic bacteria from lesions in the cow. These matters are discussed in the chapters on Hygiene and Diseases of Cows and on Transmission of Infectious Diseases, and need not be referred to at greater length in this connection. Any disease during the progress of which the cow shows an elevation of body temperature renders the milk unfit for use.

In addition to the health of the cows the inspector will also take note of the thoroughness of grooming as evidenced by the cleanliness of the cows; the condition of the stable with reference to construction, cubic space per cow, ventilation, lighting material used in construction, sewage disposal, bedding, removal and storage of manure, and kind, storage and quality of feeding stuffs. He will also observe whether horses are kept in the same stable and whether all parts of the stable are thoroughly cleaned.

Furthermore the inspection of the premises must also include an examination of the water supply for watering the cows and for washing the milk utensils. In the examination the distance of the water

supply from the stable and possible sources of pollution will receive chief attention. Observations will be made on the condition of the milkers, utensils, care of the milk and every operation and feature of the farm which can in any way influence the character of the milk. In conversation with the dairyman the inspector will learn his attitude toward the question of improvement of the milk supply. The last point is of considerable importance, for the intelligent dairyman can produce sanitary milk under conditions in which the careless man would fail.

CHAPTER VI.

MILKING AND THE HANDLING OF MILK

As should be evident from a moment's consideration, the greatest opportunity for the contamination of milk is found on the farm in connection with the milkers, the cows, methods of milking, care of dairy utensils and the care of milk in preparing and transporting it to the customers. The major part of the responsibility for the production of pure milk, therefore, rests with the dairyman himself. This does not, however, relieve the consumer of all responsibility, for it is easily possible for the milk to become contaminated by unhygienic treatment after it is received in the house of the consumer. The undesirable changes which may take place in milk occur more rapidly after the milk is delivered to the various houses of the milk route if no especial care is taken to keep additional dirt and bacteria from falling into it and if no attempt is made to cool the milk to a temperature at which the ordinary milk bacteria will not multiply.

Health and Habits of Attendants.

One of the first considerations in the production of sanitary milk is the health and personal habits of the milkers and attendants of the cows. If these men are affected or come in contact with other persons who are affected with contagious diseases, the virus of these diseases may become attached to the hair or skin of the cows and may thus gain entrance to the milk, or the virus may pass directly from the hands or clothing of the milker to the milk or milk utensils. Attention has frequently been called to the fact that it is impossible to lay too much stress upon the condition of the milker. As stated by Marshall, if the milker is an individual who is naturally clean and particular about his personal habits, the milk will be as satisfactory from a hygienic standpoint as can be produced under the conditions which prevail at the dairy. If on the other hand the milker is untidy and has filthy habits it is impossible to predict what kinds or amounts of filth and contamination may find their way into the milk.

Much has been written by way of calling attention to this point and yet its importance has been greatly underestimated by many of the less progressive dairymen. Uncleanliness and filthy habits are not tolerated in a cook or in any person who has to do with the preparation and serving of any of our other kinds of food. Nevertheless milk is often produced in stables and under conditions in which it is absolutely impossible that a clean article could be obtained. Moreover, milk is more susceptible to contamination and dirt than most of our other articles of food and after it has become contaminated with dirt and bacteria it undergoes fermentative changes and deteriorates more rapidly than any other articles of diet.

The progressive dairymen throughout the country have clearly realized the importance of this matter and insist upon cleanliness of clothes, hands and person in all milkers. It is recognized that there are almost innumerable operations which occupy the farmer's time and energies, but dairying must be considered a special industry, requiring special attention to sanitary details. While it may be troublesome to put on a fresh suit of clothes at milking time, used for no other purpose, this is commonly considered as a necessary factor in the production of sanitary milk. If the dairyman has only a few cows and is fully alive to the necessity of sanitary precautions in the care of milk it may not be necessary to insist upon the use of a special suit for milking. If on the other hand dairying is engaged in as a business, the exclusive use of milking suits at milking time must be required.

Not only must the suits which the milkers wear be clean and uncontaminated but it is also necessary for them to give particular heed to the condition of their hands. Any dirt or bacterial contamination on the hands may readily gain entrance to the milk during the process of milking. In fact it is almost impossible to prevent such an occurrence if the hands are not properly cleaned. It is only necessary to call to mind innumerable ways in which the hands of the attendants of a dairy stable must become contaminated in doing their ordinary work. Therefore it seems unnecessary to call attention further to the necessity of a careful cleansing of the hands before milking the cows.

If it seems too great a hardship to make a complete change of outside clothes before milking, it may be satisfactory to use a long cotton coat, which may be cleaned at frequent intervals and put on over the other clothes at milking time.

It is not only necessary that the milker should avoid coming in contact with anyone suffering from an infectious disease, but he should also be in good health, or at least free from any contagious disease. In this connection the greatest danger occurs in the case of men who begin to milk cows too soon after convalescing from some contagious disease. It is well known that contagion may persist on the hands or in other parts of the body for considerable periods after the individual has regained his health. Thus in scarlet fever the process of desquamation may be delayed unusually long, particularly on the hands, and small parts of the skin containing the virus of scarlet fever may be rubbed off the hands and fall into the milk. Again, in typhoid fever, the bacilli persist in a virulent form in the urine and other excretions of the body sometimes for months after recovery from the disease. Wherever this is the case it is possible for such an individual to contaminate the milk unless the point is kept distinctly in mind. After the occurrence of diphtheria the bacilli do not remain in the throat for so long a period, but it could easily occur that persons could feel well enough to milk cows before the contagion had entirely disappeared from the throat. If such should be the case the diphtheria bacilli might easily be thrown into the milk by coughing. The same is true of cases of

tuberculosis. No tuberculous individual should under any consideration have anything to do with milk. The bacilli are readily thrown in coughing and some of them would gain entrance to the milk, while others might contaminate the stables. From this contamination cows might become affected or the bacilli might subsequently gain entrance to the milk in the stable dust.

Moore has called attention to the fact that a large number of epidemics of typhoid fever, diphtheria, scarlet fever and measles have been traced directly to the milk supply and in a considerable percentage of these cases an explanation of the infection was found in the presence of the contagious disease among the milkers or in their homes. Dairymen should remember that a quarantine in case of the prevalence of such diseases should not be confined merely to the avoidance of contact with susceptible individuals but should also extend to a protection of the milk supply.

In the plan for the improvement of market milk suggested by Pearson the following rules are laid down regarding the milkers:

"Before commencing to milk the milkers' hands shall be carefully washed, using soap and nail brush, and then rinsed in clean water. A special set of clean outer garments of white cotton or linen and cap shall be worn during milking and at no other time; when not in use these must not be kept in the stable or living room but in a clean and ventilated place."

Every dairyman knows that some milkers are far more successful in securing clean milk than are others. It has frequently been observed that some of the men who milk cows in large dairies always bring to the milk room milk which is reasonably clean, although the general conditions of the dairy are not favorable for the production of hygenic milk. Stocking has called attention to the desirability of noting the personal habits of men before hiring them to attend cows. A comparative test of the bacterial content of milk showed a great variation, which was due to the care observed by different milkers. Thus the number of bacteria per c. c. of milk varied from 388 to 6150 in a test in which all the conditions were the same for the different milkers. All of the milkers were required to follow the same course of procedure in this test. The care with which instructions were carried out, however, was obviously very different in different men. As a rule the dairy students at the Connecticut Agricultural College were much more effective in preventing the contamination of milk than ordinary men hired to milk the cows. For example, the average number of bacteria per c. c. in milk drawn by students was 914 as compared to 2846 in that drawn by ordinary milkers. It is obviously a matter of the conscientiousness of the individual milker. A long and perfectly satisfactory set of regulations may be drawn up and posted in the dairy stable and all the milkers may be compelled to follow these instructions. Nevertheless it is possible to follow them in such a perfunctory way that the desired results are not attained. It is also obvious that a

milker by the exercise of common sense and the most obvious sanitary precautions may produce milk of satisfactory quality.

Cleanliness in Milking, Cleaning Cows, etc.

In milking cows to obtain pure milk, attention should first be given to the condition of the cows. The hair and skin of the cows may become contaminated with all kinds of filth, particularly manure and the other dirt or dust of stables and yards. All of this naturally contains an unusually large number of bacteria which will influence the keeping quality of the milk, although they may not render it pathogenic. The most obvious way of preventing the manure and other filth on cows from gaining entrance to the milk is to clean the cows thoroughly[4] before milking. A thorough grooming and brushing, however, may not be entirely satisfactory. This process will remove the coarser particles of filth but will loosen up finer particles which readily fall from the hair during milking as a result of the movements of the cow or rubbing the arms of the attendant against the hair of the cow. The most satisfactory way of preventing this fine dust from falling into the milk is to moisten the udder and those portions of the cow from which the dust could readily fall into the milk.

In a test at the Storr's Experiment Station ten cows were divided into two lots of five each, one lot receiving no especial care before milking, while the other five cows had the flank and udder wiped with a moist cloth, without using any antiseptic. In this test it was found that the average number of bacteria per c.c. of milk from cows which had been wiped with a damp cloth was 716 as compared with 7058 from cows which had not been treated. The highest number of bacteria in any sample of milk from cows which had been wiped was 3025, while in the case of one cow which had not been wiped the number was 15,475 and in another 64,590. These results call attention sharply to the value of taking this precaution of wiping cows with a damp cloth before milking. It prevents the contamination of the milk with such enormous numbers of bacteria.

While the general benefit of properly cleaning cows is almost universally recognized, it is not desirable to brush the cows at milking time or immediately before milking. Attention has already been called to the fact that the hair and skin of the ordinary cow carry a large number of bacteria in the filth which becomes lodged on these parts. If this material is in a dry dust form, brushing just before milking sets it floating in the air, from which it may gain entrance to the milk. Thus in a test of this matter at the Storr's Experiment Station the average number of bacteria per c.c. of milk from cows not brushed at milking time was 1207 as compared with 2286 from those which were brushed at this time. The operation of grooming should obviously be done some time before milking or afterward.

In connection with the danger of contamination of the milk from dust loosened from the hair and skin of the cows, it should also be

remembered that feeding hay just before or at milking time also adds greatly to the dust in the atmosphere of the stable. Corn stover and other dry feeds should also be withheld from the cows at milking time. In Pearson's proposed plan for the improvement of milk it is recommended that "milch cows shall be groomed not more than one hour before every milking. A stiff brush shall be used to remove dry matter and places soiled with fresh manure shall be cleaned by washing. Long hair on the udder and flank shall be clipped."

The suggestions made above regarding the cleaning of cows seem to be highly desirable when we consider the condition of the udder and flanks of dairy cows on premises where no special attempt is made to keep them clean. It is not an uncommon sight to see the flanks and hind quarters of cows literally plastered over with dried manure in a coat from one-quarter of an inch to an inch in depth. In such cases it is absolutely impossible to prevent contamination of the milk. Some of this filth will fall into the milk no matter how great precautions are taken. It is well to remember, as suggested by Pernot, that cows which have access to stagnant water in summer almost invariably wade in the water to escape from flies and to cool themselves. The udders and teats thus become submerged in water which may be muddy and which may contain not only ordinary bacteria which cause fermentation and putrefaction, but also typhoid bacilli and occasionally other pathogenic bacteria. This filth after drying on the hair of the cows may be brushed off into the milk at milking time if the cows have not been previously groomed.

Marshall has shown that even a comparatively clean hair from a cow may have on its surface from 50 to 3000 bacteria. Hairs covered with filth will obviously carry a much higher number of micro-organisms. The objection to hair in milk is therefore not due merely to the presence of the hair itself as a foreign body but to the fact that such large numbers of bacteria are transferred to the milk in contact with the hair. In view of this fact it is apparent that special precaution should be taken to groom the cows so as to remove the loose hair as fully as possible, particularly during the season when the coat is being shed.

Methods of Milking.

Dairymen have given much attention to rational methods of feeding cows and the sanitation of cows in stables but until recently little heed has been given to the matter of milking. This operation, however, is as important as any other connected with the business of dairying. It has long been known that some milkers are more efficient than others in that they secure a larger quantity of milk at each milking or succeed in maintaining the milk flow more uniformly and for a longer time. From the view-point of securing an adequate and sanitary milk supply the methods of milking are worthy of consideration for the reasons that it may thus be possible to secure more milk and milk of a better quality.

The variation in the work done by different milkers lies largely in the amount of attention which they give to the final process in milking. Some men are able to strip the cows cleaner. This has led to a number of practical tests for the purpose of determining the difference in the amount of milk obtained by a thorough stripping or removal of the residual milk. It is commonly considered that the average milker can obtain all the milk, or at least milk the cows sufficiently clean for practical purposes, merely by the ordinary process of stripping. In 1900, however, a method of milking was originated and recommended by a Danish dairy school teacher, Dr. J. Hegelund, and is designed to remove the residual milk more completely than any other known method of hand milking. The introduction of this method into the United States is largely due to the efforts of Professor F. W. Woll, of the Wisconsin Experiment Station.

The Hegelund method of milking consists in a series of manipulations of the udder, which are carried out by the milker as soon as the main flow of milk has stopped. The manipulations as described by Professor Woll are essentially as follows:

In the first manipulation the right quarters of the udder are pressed against each other, the left hand on the hind quarter and the right hand on the fore quarter, the thumbs being pressed on the outside of the udder and the forefingers in the division between the two halves of the udder. If the udder is unusually large one quarter is taken at a time. The hands are pressed towards each other and at the same time lifted upward, this pressure and lifting being repeated three times. The milk thus collected in the milk cistern is then milked out and manipulation repeated until no more milk can be obtained in this way. The left quarters are then treated in the same manner.

In the second manipulation the parts of the udder are pressed together from the side. In this operation the fore quarters are milked one at a time by placing one hand with the fingers spread on the outside of the quarter and the other hand in the division between the right and left quarters. The hands are then pressed toward each other and the teat milked. When no more milk is obtained the hind quarters are treated in the same way.

In the third manipulation the fore teats are grasped in the partly closed hands and pushed upward at the same time, the milk being drawn after each three movements. As soon as the fore teats are emptied the hind teats are milked in the same way.

This method has been carefully tested by a number of dairy experts and commercial dairymen. At the Cornell Experiment Station Wing carried out a set of experiments to determine the value of the method. The cows were milked in the usual way by the regular milkers. As soon as a milker had finished a cow she was again milked by the Hegelund method. The amount of milk thus obtained was weighed and the percentage of fat determined by test. The milkers in this case were instructed to take no unusual pains in milking the cows in

order that the test might be a fair one. In the first experiment it was found that the residual milk obtained by the Hegelund method was not detrimental to the production at the regular milking; or expressed in other words the milk was all gain. The amount of milk secured from each cow weekly by after-milking by the Hegelund method varied from 3.75 to 13.5 pounds and the amount of milk fat from .5 to one pound, the average gain per cow per week being 8.75 lbs. of milk and .6 lbs. of fat. In a second test of the Hegelund method by Wing, the average gain in milk for each cow weekly was 1.9 lbs. and .55 lb. of milk fat. When the method was applied to the herd of a neighboring farmer containing nine cows the daily profit from the use of the Hegelund method at the usual price of butter was 38c. These experiments indicate that there is a considerable financial loss in many dairies as a result of careless milking and that the milk thus left in the udder is lost. It appears to be desirable from every standpoint to secure all the milk secreted by the cow at each milking. This requires but very little extra time and it is probable that clean milking has a tendency to increase the production.

A thorough test of the Hegelund methol was carried out by Professor Woll with cows in the herd belonging to the University of Wisconsin and in twelve commercial dairies. This elaborate series of experiments gave reliable data not only on the value of the Hegelund method but on the character of work done by different milkers. According to Woll the average daily poduction of milk was increased 4.5% and the fat 9.2%. In a test of the Hegelund method which was continued for four weeks the average daily gain per cow was one pound of milk.

A similar average increase in milk yield was obtained for the twelve commercial herds in which the Hegelund method was tested, the milk yield being incheased 1.08 lbs. and the fat .1 lb. per cow daily. The experiments as a whole were continued over a period of four months with cows in all different stages of lactation and indicated that the gain was a substantial one during all the stages. As estimated by Woll, if the fat production of each cow in Wisconsin be increased by .1 lb. per day it would mean an annual increase of 30,000,000 lbs., it being assumed that cows give milk for 300 days in the year. In these tests the greatest amount of milk obtained by the Hegelund manipulations after the regular milking had been done was 5.5 lbs. per day. Naturally the greatest gain from the application of the Hegelund method was shown in herds which were carelessly milked, but even after careful milking the manipulations yielded nearly a pound of milk per cow.

It should be remembered that the milk obtained by the Hegelund manipulations is very similar in composition to that of strippings. In Woll's experiments the milk thus secured contained 10.3% fat, being about two and a half times richer than ordinary milk. The highest percent of fat observed in the after-milking was 23.

A careful computation of the increased amount of milk due to careful milking indicated that some milkers may be worth as much as $10 per month more to the dairyman than other milkers, merely on account of the greater amount of milk obtained.

From a sanitary standpoint there are no objections to the Hegelund method. In fact it has the considerable advantage that bacterial infection of the udder is greatly reduced as a result of the more complete removal of the milk. It is well known that the foremilk obtained at the beginning of milking is relatively rich in bacteria and this means simply that the milk left in the milk cisterns from the previous milking has served as a culture medium for the growth of bacteria.

Milking machines.—The rapid strides made in modern dairying are to a large extent due to the invention and successful use of effective machinery. The rapid increase in the size of our large cities and the increased demand for milk have caused a great development of the dairy industry and this in turn has brought about an increased demand for milkers. Recently the difficulty of obtaining farm labor of all kinds has been increasing and this is particularly true of milking, which is considered one of the most unpleasant tasks on the farm. The work is very exacting and confining. It must be done at regular hours and there is no escape for holidays or vacation. Recently, therefore, many inventors have turned their attention and energy in the direction of perfecting milking machines in order to relieve the stress into which dairymen have fallen.

According to the investigations of Professor Erf at the Kansas Experiment Station, inventors were working on milking machines as early as 1819, but it was not until 1878 that a really practical machine was devised. There are three principles upon which mechanical milking devices are based. The first apparatus was a milking tube, which provides an opening into the milk cistern and allows the milk to flow out. A great variety of these tubes have been devised and in some instances even such a simple device as a straw has been used. The great danger from the use of milk tubes is that infection may be carried into the udder if the instrument is not strictly sterilized before using.

In a second group of milking machines pressure is applied at the base of the teat next to the udder. The operation of machines constructed on this principal is essentially the same as that observed in hand milking.

The third principal utilized in milking machines is suction. Cups from the air is exhausted, thus producing a vacuum, are placed over the teats. The pressure of the air on the udder thus forces the milk out into the vacuum chamber. This principle is essentially the same as that utilized by the calf in sucking. In fact considerable energy has been expended in trying to imitate as nearly as possible the action of the calf's mouth, in the operation of these machines.

At least five well known milk tubes, 25 pressure machines and 42 suction machines have been invented and put into use in the United States. According to Erf, the Kansas Experiment Station has had in successful operation the Burrell and the Globe machines, the former having been used more extensively. In the various suction machines the vacunm is produced either by a vacuum pump, a steam jet air exhauster, or a water vacuum pump. On most farms the mechanically operated vacuum pump is most practical. Boilers are ofter in use on dairy farms and a steam jet air exhauster is simple and efficient. The chief objection to this device as urged by Erf is that there may be irregularity in milking if the operator should allow the steam pressure to go down. The water pump vacuum cannot be used except where there is an abundance of water at high pressure. For running a vacuum pump system electricity or gasolene may be used as a motive power or denatured alcohol if that product should become sufficiently cheap. In Erf's experiments it appeared that the power required to operate the vacuum pump may be estimated at the rate of one horse power for each cow in small dairies, but the power required is relatively much less in large herds. The piping of the vacuum system is preferably conducted along the top of the stanchions. Professor Erf recommends that the stall pipes should not be less than one inch in diameter and that the pipe leading from the stall pipe to the vacuum pump should be at least 1¼ in. in diameter. If the Globe machine is used a compression pipe is also necessary in connection with the vacuum pipe. This arrangement is added to interrupt the suction and produce pulsations resembling the sucking movements of the calf. A safety valve is to be attached to the system to prevent too great negative pressure from the vacuum

As has been well said by Erf and others, the practical value of a milking machine depends upon the reduction in the cost of labor, the elimination of hand milking, the maintenance of the quantity and quality of the milk, clean milking with adaptability of the machine to the average cow, reliability and securing returns corresponding to the capital invested. In Erf's experiments the saving of labor under average conditions was estimated to be from 30 to 40%. This allows the dairyman to hire fewer but more efficient laborers. In a comparison of hand milking and machine milking it appeared that on an average about one pound of milk per minute was drawn by hand, the average number of strokes being 106 per minute and the average time for the milking of each cow nine minutes. With the use of machines 2.4 lbs. of milk were drawn per minute and the average time required for each cow was seven minutes. But it should be remembered, however, that a single machine may be attached to two or more cows at the same time. In experiments along this line by Lane, there was a daily saving of 3.5 minutes per cow through the use of the machine. The number of pulsations in the vacuum system

may be 150 or more per minute, which is considerably in excess of the number of movements by the ordinary milker.

The use of the milking machine relieves the workman of the objectionable part of hand milking. The necessary movements of hand milking are tiresome and the work itself is disagreeable at all times and particularly so in exceedingly warm or cold weather.

In Erf's experiments with milking machines the quantity of milk was somewhat reduced from their use in the case of some cows, while in others it was increased. The quality of the milk was practically the same whether obtained by hand milking or by machines. In Lane's test there was a slight difference in the amount of milk in favor of the machines. It was found, however, that where milking machines were used carelessly they are a disadvantage to the dairyman from the standpoint of milk yield, and actual loss in the quantity of milk may be suffered if the machines are not carefully manipulated. In Kansas experiments it appeared that the average cow milked somewhat cleaner by machine than by the average milker.

With regard to the cleanliness of the milk obtained by the use of machines as compared with that secured by hand milking, there was a slight difference in Erf's experiments in favor of the machines, the number of bacteria in the machine-drawn milk being somewhat less. It is urged, however, that great care be taken to wash the teats of the cow thoroughly before the milking cups are attached, otherwise the suction and pulsating movements will dray large quantities of dirt and bacteria into the milk. Particular attention must be given to cleaning the machines after they have been used. This must be done before the milk has dried on the cups and tubes. It is commonly recommended that the machine, while connected together as for milking should be operated to suck cold water and afterward warm water, thus rinsing all of the tubing. This should be followed with hot water containing sal soda or caustic soda. All parts of the pulsator must be washed with a brush and rinsed in boiling water, after which it is set aside to dry. As an antiseptic for cleansing the parts of the milking machine boracic acid has been found expensive and ineffective but has the one advantage that it preserves tin. Formaldehyde appears to be the most effective but lime is cheapest and perhaps most practical on a large scale.

The careful bacteriological studies made by Stocking in determining the sanitary relations of the milking machine indicate that unless care is used in cleaning the machines decomposing milk and bacteria accumulate in the rubber tubes and contaminate the milk as it passes through. Stocking is of the opinion as the result of his observations that the majority of the dairymen who are now using machines are not taking sufficient precaution in sterilizing these machines. Their milk is therefore of poorer quality from a sanitary standpoint than that drawn by hand. If, on the other hand, the milking machine is kept in a sanitary condition, machine-drawn milk contains much

smaller numbers of bacteria than hand-drawn milk. In the experiments under discussion the number and percentage of liqnifying bacteria were considerably reduced by the use of machines and the keeping quality of the milk was increased. The use of cold water followed by hot water containing sal soda is not sufficient to prevent the multiplication of bacteria in milking machines. The same may be said for merely scalding by pumping boiling water thorugh the machines and for subjecting the machines to steam without pressure for a period of thirty minutes. In Stocking's experiments where the rubber parts were placed in brine for several hours, after being washed or boiled in water containing powdered borax, a satisfactory sterilization was brought about, and the bacterial content of the milk was reduced. These tests indicate clearly that with careless management milking machines lower the quality of the milk but that when machines are carefully managed and sterilized the quality is improved.

Erf found in the use of milking machines that if the vacuum is normal and the cups fit the teats well the process of milking seems to annoy the cows less than hand milking. Some cows which cannot be milked by hand can be easily milked by machines. In the reports received by Lane from 11 dairymen it appeared that the effect of the machines upon the teats and udders was in no way objectionable and that the effect upon nervous, kicking and hard-milking cows was very favorable. Rarely the operation of the milking machines seems to annoy the cow. As a rule, however, it appears that the hard-milking cow is more easily managed by machine than by hand. The machine also seems to be especially adapted to heifers.

The financial considerations in connection with the purchase and operation of a milking machine will depend partly upon the number of cows in the herd. According to calculations made by Lane, the total cost of an engine or other power, a vacuum pump, vacuum tank, pipe and four milking machines for a herd of forty cows is about \$516, or from \$8.50 to \$13 per cow, depending upon the size of the herd. Erf is of the opinion that in the small dairy the investment in a complete milking outfit would scarcely be justified.

It has been found that the continued use of milk tubes has a bad effect upon the milk flow. The yield is diminished to such an extent that their use cannot be recommended. This result which has been frequently observed in addition to the danger of infecting the udder by using milk tubes should be sufficient to condemn them for ordinary purposes. As already indicated, however, milking machines have not proved to be objectionable from this standpoint. The cows apparently yield no less at any given milking than when milked by hand and the milk flow is maintained by the use of the machine with a total milk yield during the whole period of lactation as great as could be obtained by hand. The use of machines, however, is still somewhat in an experimental stage and has not been adopted on a scale which renders them of much importance in the dairy industry.

Rejecting the Foremilk.

Dairymen who put forth a special effort to produce clean milk with a low bacterial content make a practice of discarding a few of the first streams of milk or the foremilk as it is commonly known. Numerous experiments by dairy bacteriologists have shown that the first few streams of milk contain a much larger number of bacteria than the rest of the milk obtained at each milking. In order to get rid of these bacteria it is not necessary to discard more than about four streams from each teat. A careful series of experiments have been carried out by Stocking to determine the significance of rejecting the foremilk in the problem of reducing the total number of bacteria in the milk. The first two streams of milk from each quarter of the udder were found in every case to contain decidedly more bacteria than the fifth and sixth stream of any of the milk subsequently obtained. After ten streams had been removed from each teat the germ content of the milk did not vary greatly during the rest of the milking. From these experiments it would appear desirable to discard about six streams of milk from each quarter of the udder before saving the milk for use.

As suggested by Stocking it might be supposed that while the first few streams of milk contain large number of bacteria, the total number of bacteria in the milk would not be greatly influenced when all the milk was mixed together. A test of this matter under carefully controlled conditions showed an average of 522 bacteria per c.c. when the foremilk was not rejected and 499 when the foremilk was not added to the rest of the milk. In this case the bacterial content of the milk was very low, whether the foremilk was rejected or not, the relative cleanliness of the milk being due to the sanitary precautions observed. The rejection of the foremilk, however, showed a distinct advantage in the reduction of the number of bacteria.

It has already been suggested that there are at least three reasons why cows should be thoroughly milked at each milking. Careful stripping or the adoption of the Hegelund method of milking insures a larger yield at each milking and maintains the milk flow at a higher point. From a sanitary viewpoint it is also desirable to remove the milk from the udder as completely as possible at each milking. Any milk which may be left in the milk cistern at the base of the teat is subjected to infection with bacteria which make their way through the milk canal. If these be ordinary milk bacteria no harmful infection of the udder will result but they may multiply to a great extent during the twelve hours which elapse before the next milking and this is the explanation of the high bacterial content in the foremilk, for the foremilk is for the most part the milk which was left in the milk cistern at a previous milking.

In experiments carried out by Stocking and others it was found that in the majority of cases the bacterial content of the milk was considerably higher when some of the strippings had been left in

the udder at the previous milking. In many cases the difference was very marked. Rarely, for some reason not easily understood, the germ content was higher in the cows which had been thoroughly milked. This must mean, however, that these cows had been subjected to greater chances of infection with milk bacteria than the other cows which had not been stripped. While the udder of the cow may be kept relatively free from milk bacteria by careful and thorough milking and by furnishing the best practical sanitary conditions for the cows, it must be remembered that no amount of effort in this direction can keep the udder germ fee. It is therefore necessary to reject a few of the first streams at each milking. A part of the significance of the Hegelund method, in this connection, lies in the fact that the thorough manipulation of the udder in this process serves to dislodge some of the bacteria in the milk ducts and prevent the inevitable multiplication which would take place in these organisms if they were left in the udder until the next milking.

Russell obtained some very suggestive results from experiments along this line. In one experiment the number of bacteria per c.c. gradually diminished from 6500 in the foremilk to 5 in the strippings and in another from 8100 to 10. These figures refer merely to ordinary milk bacteria which are not pathogenic for either man or the cows. The importance of thorough stripping becomes still more apparent, however, when it is remembered that pathogenic bacteria might easily gain entrance to the teats and there find opportunity for enormous multiplication if the strippings were not thoroughly removed. The matter is of greatest importance in stables which are not of the most sanitary construction or where cows are subjected to an excessive infection with bacteria which may be found in the manure and filth of the stables. If an outbreak of contagious mammitis or garget should take place in the stable a thorough stripping of the cows at each milking would become even more imperative in order to prevent the undue spread of this disease.

The Use of Covered Pails.

Nearly all pails used for milking purposes are larger at the top than at the bottom and in order that the size may be sufficient to hold all of the milk of any cow the diameter at the top must therefore be relatively large. This gives a large surface for the reception of bacteria which may fall from the udder or flanks of the cow, or which may gain entrance from the atmosphere of the stable. In order to reduce the surface over which bacteria may enter the milk of the pail, a large number of pails have been patented in which much of the top is covered over in order to reduce the open surface as much as practicable. There is obviously a practical limit to the reduction of the opening in the top of the pail for the reception of milk, but within this limit covered pails have been found to serve reasonably well the purpose for which they were devised.

Numerous comparative tests have been made of such pails, one of the most extensive being that of Stocking at the Storr's Experiment Station. This investigator made two sets of parallel tests: in one case milk drawn into an ordinary open pail was compared with milk drawn into a covered pail devised for excluding dirt; and in the other case milk drawn into an open pail was compared with that strained immediately after milking. When the milk was examined for the presence of dirt it was found that the milk in covered pails contained only 37% of that in open pails, while the amount of dirt in strained milk was more than half as much as was found in unstrained milk. It is apparent therefore that the covered pail excluded 63% of the dirt, while the strainer removed less than half.

Furthermore in these experiments the covered pail was found to exclude 29% of the total bacterial content and 41% of the acid-producing bacteria, while by straining milk only 11% of the total number of bacteria was removed.

It is of even more importance to note the effect of covered pails upon the number of bacteria in the milk after it has been allowed to stand for a reasonable length of time. In Stocking's test after milk had stood fifty hours at a temperature of 70 degrees F., samples from the covered pail contained a smaller number of total bacteria and always contained fewer acid-producing bacteria. On the other hand in strained milk the total number of bacteria and the number of acid-producing bacteria was higher than in milk which had not been strained. Samples of milk from covered pails as a rule curdled somewhat sooner than similar samples from open pails and the same was true of strained milk.

While it may not be an easy matter to explain why the keeping properties of milk are not always improved by the use of covered pails, it should be remembered that in the above-mentioned tests the milk was kept considerably longer than is the case in ordinary households and at a temperature above that which the housewife uses for preserving milk. As urged by Stocking, the demand of the milk-consuming public is not for milk which can be kept indefinitely but for milk which may be used with reasonable promptness by children and adults without danger to health. In this respect the use of covered pails accomplishes all that could be expected of them. As compared with straining the results are all in favor of the covered pail. This matter will be referred to further in the next section.

Straining, Filtering, Purifying, Aerating and Cooling Milk.

Nearly all dairymen strain the milk as soon as it has been drawn and this practice is almost universally recommended in publications relating to the care of milk. Milk drawn under ordinary conditions which prevail on the average dairy farm becomes contaminated to a greater or less extent with dirt, dust, hair and other foreign bodies which invariably carry bacteria. Straining has therefore always been

recognized and recommended as a practical means of removing this filth. Too much reliance, however, should not be placed upon straining, since as already indicated and as will be discussed further straining may not reduce the number of bacteria in the milk.

A large variety of strainers have been placed upon the market and are in common use. In some cases the milk pail is furnished with a partial cover on one side, in the center of which there is a wire strainer with fine mesh. When such pails are used for milking the milk is allowed to run through the strainer immediately after it is drawn. This is perhaps the least satisfactory of all forms of strainers. The meshes cannot be made fine enough to remove the minute particles of dirt and unless the strainer is cleaned after each cow is milked and before the milk has been poured through it some hair and other dirt which will have fallen on the top of the strainer will be washed into the milk.

In other cases similar wire-mesh strainers are placed over the tops of cans or other receptacles into which the milk is poured in the milk room. These have the one advantage that the strainer is not subjected to pollution with hair and filth from the outside.

It has long been known that even strainers with the finest possible mesh will allow some filth to pass through. The attempt has therefore been made to reduce the quantity of dirt which passes through to a minimum. In order to secure this several thicknesses of fine cloth have been used of cotton or woolen texture, preferably the latter. Some dairymen have made use of a strainer consisting of a layer of cotton batting with a layer of fine cloth above and below.

It should be understood at the outset that bacteria are much smaller than the fat globules in milk and strainers therefore cannot have the least effect in reducing the bacterial content of milk. In fact if cloth, cotton batting or wire strainers are not thoroughly cleansed at frequent intervals bacteria will multiply in the milk particles which adhere to such strainers and will be washed into the milk receptacle with the stream of milk. The number of bacteria in the milk will thus be increased rather than diminished.

Marshall has called attention very pertinently to the fact that altogether too much energy is expended upon the straining of milk. Cheesecloth has a comparatively loose texture and it is obviously impossible by the use of a sieve with a one-fortieth inch mesh to intercept bacteria which are one-ten-thousandth of an inch or smaller in diameter. Conn, Marshall and many other dairy investigators have called attention to the fact that all soluble filth will be dissolved and washed through the strainer however small the meshes may be. If, for example, comparatively large particles of manure or other soluble filth should be caught by the strainer at first, these particles will soon be dissolved by the stream of milk and washed on through the strainer. Moreover in this process nearly all of the bacteria which may be attached to hair, straw or other insoluble particles of foreign matter will likewise be dislodged and washed into the milk.

In the exhaustive experiments of Conn it has been clearly shown that the number of bacteria is the same in strained and unstrained milk. Straining therefore as ordinarily practiced merely removes the visible particles of filth, while all of the soluble manure or other dirt readily passes through the strainer. The dairyman is practically under the necessity of straining milk, since his customers would strenuously object to the presence of hair or other visible particles of filth in the milk. Nevertheless, dairymen understand that even after milk is strained the amount of filth really present in the milk is essentially the same as before and the milk inspector will find by a bacteriological test that the germ content has not been affected.

It is desirable to strain the milk in all cases, but if it were drawn with sufficient care straining would not be necessary. It is obviously far better and more sanitary to prevent filth and bacteria from gaining entrance to the milk than to attempt to remove this material later by the device of straining. Moreover in order to prevent the use of strainers from becoming a positive disadvantage it is quite necessary that the strainers should be frequently cleansed with boiling water, steam or by some other antiseptic method and for this purpose it is best to have several strainers for use during each milking.

A number of filters have been devised for purifying milk. These have been constructed of paper, cellulose, gravel, sand, porcelain and other materials. The filters used for this purpose are operated on essentially the same plan as in filtering water to bring about a reasonable purification. Milk filters are scarcely practicable in a small dairy for the reason that they are somewhat expensive and require too much time for operation and for properly cleaning them. In the case of milk dealers who handle a large quantity of milk it may be desirable to establish a sand filter, in which the milk is forced upward through a deep layer of sand. After each filtering process the sand must be removed, cleansed, baked and dried. Such sand filters insure the removal of filth somewhat more effectively than the ordinary strainer but do not greatly reduce the bacterial content of the milk. A filter of this sort used in Norway was found to be much more effective than an ordinary strainer.

In considering the problem of purifying milk after it has been drawn it should be remembered that the germ content of such milk is practically proportional to the amount of dirt. As shown by Backhaus about one-half of the fresh cow dung which falls into milk dissolves so that it cannot be estimated by any common method for the determination of the amount of dirt. For such determination it is sometimes recommended that the milk be allowed to settle and be filtered through glass wool.

Since sieves, strainers and filters are not found satisfactory in cleaning milk, resort has been had to purification of milk by means of the separator. From a mechanical and bacteriological standpoint this is quite satisfactory. Nearly all of the dirt and bacteria in milk have

a higher specific gravity than the milk and are therefore removed in the centrifugal slime. Many experiments have shown that separator slime in the case of milk from tuberculous cows contains nearly all of the tubercle bacilli and is very dangerous for feeding to pigs without previous sterilization. It has been found possible to remove a large part of the dirt and most of the bacteria in milk by running all of it through a separator and later combining cream and milk. There are some disadvantages attached to this method, however. In the first place considerable labor is involved in the process of separation. Then it is claimed that after separation and subsequent mixing of the cream and milk, the cream does not rise as thoroughly and completely as in untreated milk and this matter led to suspicion in the minds of milk customers and to complaints about the fat content of the milk. Moreover where the method of purification by separation has been adopted on a large scale in cities where the established milk standard sets a relatively low minimum of fat it is possible for milk dealers to separate all of the milk and remix with the skim milk only enough cream to bring the mixture up to the required standard. In some localities complaints to this effect have been made by the dairy farmers who feel that they are thus done an injustice and that the milk dealers are receiving an unearned profit. In some tests of purification of milk by separation evidence has been obtained that it is best to carry out this process after the milk has cooled. The fat separation may not be as complete in cold milk but this fact is of no significance since the fat is to be mixed again with the skim milk.

It has long been believed and many experiments have appeared to indicate that there are considerable advantages in the prompt aeration of milk. As milk is ordinarily cooled by allowing it to trickle over the surface of corrugated metallic coolers aeration is accomplished at the same time as the cooling. These combined coolers and aerators are in wide use among progressive dairymen. In the United States some of the most extensive experiments to determine the effect of aeration upon the condition and bacterial content of milk have been carried out by Marshall at the Michigan Experiment Station. In the ordinary gas content of milk this investigator found that on an average 81.5% was carbon dioxide and 2.4% oxygen. Aeration reduced the content of carbon dioxide 35% and oxygen 20%. The presence of carbon dioxide in milk was found to be of more benefit since when present in quantities exceeding 33% it appears to restrain or prevent the growth of bacteria.

Marshall has well called attention to the fact that milk undergoes a process of aeration from the time it leaves the cow until it is consumed. This process is indicated by the diminution in the amount of carbon dioxide and the increase in the amount of oxygen. Any aerating method which increases the exposed surface of the milk facilitates aeration. It should be remembered that while the milk is exposed in thin layers for the purpose of aeration abundant oppor-

tunity is offered for the absorption of disagreeable odors and undesirable gases unless the operation is carried on in a pure atmosphere.

As a result of his study of the aeration of milk Marshall recommends that it should be done before the milk loses its animal heat and that the milk should be made to flow slowly over an extensive surface. This investigator believes that aeration should be done immediately after milking and should precede cooling since in his experiments the most satisfactory results were not attained when aeration and cooling were carried on simultaneously. In certain English experiments it was found that the aeration of milk extended the time during which it remained sweet and also eliminated the animal odor. Moreover Barthel found that aeration retards fermentation to some extent.

The general subject of the refrigeration of milk is discussed in Chapter VIII and in this connection it is merely necessary to make brief mention of the subject. As indicated in the chapter on refrigeration milk bacilli multiply much more rapidly at high than at low temperatures. It is desirable therefore to reduce the temperature of the milk to 50° or 60° F. as soon as possible after milking. The temperature of 40° is still more effective, but only a comparatively small percentage of dairymen have facilities for cooling their milk down to this point. If the milk is to be delivered within a few hours after it is drawn the bacterial content will not have increased greatly. In fact during the first two or three hours it may actually diminish. If however morning milk is to be delivered at night or night milk in the morning it is necessary that cold should be applied in order to prevent the multiplication of bacteria and the premature souring of the milk. This may be accomplished as indicated in the chapter on refrigeration, by the use of spring water, other running water, ice or artificial refrigeration by means of machine.

Care of Dairy Utensils.

It is of course quite unnecessary to present any argument to the progressive dairyman for the purpose of convincing him of the necessity of strict cleanliness in connection with all vessels and utensils with which milk comes in contact. The dairyman is already assured of the necessity for such care. Nevertheless, there are still in use on some dairy farms utensils and time honored methods of caring for them which cannot be approved by modern sanitarians. In all lines of modern industry connected with the manufacture of food products great progress has recently been made in devising apparatus and methods which minimize the amount of contact of human hands and other objects which might carry contamination to the food products in any stage of the manipulation connected with their preparation for the market. The same is true in the dairying industry. Not only must all dairy utensils be clean at the time of use but in order to satisfy practical demands they must be easily

cleansed. This point is of more importance than the mere general appreciation of the necessity for cleanliness, for if milk utensils are not easily cleaned and require too much labor to remove all particles of milk and other filth which may become attached to them it is merely a question of time when the labor of cleansing will appear too great and some carelessness will be permitted.

Unclean dairy utensils are one of the important sources of contamination of milk. Any particles of milk or cream which remain attached to the utensils from a previous use serve as a medium for retaining and allowing the multiplication of milk bacteria. As soon therefore as fresh milk is placed in these utensils a portion of this partly dried milk is softened or again changed into a fluid form by the presence of the fresh milk and the bacteria which the filth contains are set free to operate in producing undesirable changes in the milk. The object of cleansing milk utensils is to remove the material in which bacteria may grow, and thus render the milk vessels sterile from a bacteriological standpoint. Millions of ordinary milk bacteria may be concealed in minute crevices or corners in sour or partly dried milk which has been allowed to remain in such places.

On account of the great difficulty or practical impossibility of cleansing them, no wooden vessels of any sort should be used in handling milk. The frequent washing to which they must be subjected and the partial drying between the periods of use sooner or later cause checks in all kinds of wooden utensils in which milk finds lodgement and from which it cannot be removed by any practical system of cleansing. Glass and earthenware vessels have been used as milk utensils and are very efficient for this purpose, answering all of the sanitary demands which could be made of such utensils. They are too expensive, however, and too easily broken, for practical use. Tinned metal answers most perfectly the practical and sanitary requirements of milk utensils. The tin however should be of good quality, heavy, and smoothly laid over the iron base of the utensils so that the rougher metal is completely covered and so that no joints, crevices, seams or corners are left exposed.

As has been urged by all dairy experts seemless utensils of pressed tin are greatly to be preferred. Milk pails should have no corners in which milk is left. Aerators, coolers, strainers and other utensils should also be smooth and with as few irregularities of surface as is consistent with their construction. The same rule should apply to dippers and delivery cans. Particular attention must be given to the cream separator after each using, for this instrument is one of the most complicated in use on dairy farms.

Erf and others have conducted a number of experiments having in view the efficiency of methods of cleaning dairy utensils. For practical purposes hot water or steam and alkali and a scrubbing brush or coarse cloth are the chief materials to be used in cleaning milk utensils. All vessels should be cleaned immediately after using and

before the milk has had opportunity to dry. Milk utensils should first be rinsed in lukewarm or cold water for the purpose of removing as much of the milk as possible. If boiling water or steam is applied at once the milk in contact with the utensils would be coagulated and would adhere much more firmly than would otherwise be the case. After rinsing in lukewarm water milk utensils should be thoroughly scrubbed with hot water to which a washing powder or caustic soda has been added. The addition of an alkali saponifies the fat of the milk and thus helps to remove it from the surface of the tin. Common commercial soaps should not be used in washing milk vessels. After scrubbing with hot water and an alkali it is desirable to apply live steam. Steam is not always accessible in small dairies but since it is the cheapest and most effective means of destroying bacteria and finishing the cleansing process a steam boiler should be installed in all large dairies.

Where steam is not to be had a five per cent solution of washing powder applied vigorously in hot water for about ten minutes will insure the proper cleansing of dairy utensils provided they are afterward rinsed with hot water. A hot solution containing ten per cent of borax will assist greatly in sterilizing milk utensils and also has the effect of helping to preserve the tin. This material, however, should be thoroughly rinsed off in order to avoid getting borax in the milk.

The old-time practice of using wash rags and various kinds of cloths in cleansing dairy utensils is not very satisfactory. These rags cannot be sterilized without thorough boiling or dipping into an antiseptic solution followed by treatment with boiling water. These operations, however, are not usually carried out and the result is that the ordinary wash rag adds far more bacteria to the surface of milk utensils than it removes. If ordinary dish cloths are to be used for wiping dairy utensils they must be steamed or boiled in a washing solution after each using. Obviously the most satisfactory and sanitary method of cleansing the milk utensils is to remove all particles of filth and milk by means of a stiff brush, rinse the surface with hot water and then apply steam, after which the utensils are allowed to dry without being wiped or touched in any way.

Detailed directions are furnished by the manufacturers of all milk separators regarding the cleansing of these machines. It is commonly observed that these directions are followed literally at first, after which in some cases a slight laxity is allowed in methods of cleansing. It is unfortunately true that separators constitute one of the important sources of the bacterial contamination of milk. For the purpose of securing evidence of the importance of the thorough cleansing of separators, Erf compared the efficiency of simply flushing out the bowl with water and of thoroughly washing the separator. Samples were then taken from milk run through the separators at the next using. In these experiments it became obvious that cream

separators must be thoroughly washed after using. For this purpose a brush and a five per eent solution of borax or some other washing powder is recommended. All parts of the machine are then to be rinsed in hot water or treated with steam and allowed to dry while hot. It was found that wiping with an ordinary cloth added immense numbers of bacteria to the parts of the separator. The bacterial contamination of the milk was found to be increased three to five times by running it through a separator bowl which had merely been flushed and allowed to stand since the previous milking. If still greater negligence were permitted in the eare of the separator the skim milk from the machine would bcome harmful even to the calves to whieh it is fed.

Reference has already been made to the use of the centrifugal separator in removing filth and bacteria from milk. If the separator is properly cleansed after each using it brings about a striking reduction in the number of bacteria in the milk. When properly cared for, therefore, a separator may be considered as a elarifier and a purifier of milk but when allowed to become eontaminated it constitutes a fruitful source of bacteria which are passed on into the milk which runs through the machine.

As an alkali for an addition to the washing water, sal soda is as convenient and satisfactory as any that ean be used on the dairy farm. After the use of such a solution it is not necessary to dry milk utensils with cloth even if no steam is available, for if rinsed with boiilng water and inverted on a clean shelf plaeed so as to receive the direct rays of the sun the vessels will dry quiekly and thoroughly.

In the plan for the improvement of market milk as suggested by Pearson attention is ealled to a number of practical points which must be observed in the care of milk utensils in order to insure a pure milk supply. Among other things it is recommended that the joints and seams of metal utensils should be made smooth and all cracks filled with solder. No old, rusty or badly jammed milk vessels should be used for the reason that they are difficult or impossible to elean. Milk utensils should not be used for any other material and none of the milk utensils except the milk pails should under any eonsideration be carried into the milking stable. Pearson also calls attention to the neeessity of cleaning all these vessels immediately after using and this cleansing should include the surfaces and parts of every utensil. It is not enough to clean merely the inside, for eontamination left on the outside of milk cans or pails may find its way into the milk in handling. When not in use all milk vessels should be kept inverted, without covers, in a clean, dry, dustless and odorless atmosphere.

General Care of Milk.

As soon as milk is drawn it should be strained through sterile cloth and absorbent cotton and removed from the stable to the milk room.

Before straining it may be quickly weighed if the dairyman desires to keep a record of the milk yield of each animal. After straining the milk should be run over a cooler, during which the temperature is reduced from body heat to about 40°. This operation occupies but a short time and of necessity allows a satisfactory aeration of the milk. The subsequent care of the milk will of course depend on the use to which it is put and the method of handling adopted by each dairyman. It may be at once bottled and capped, after which it is placed in clean boxes and kept cool by water or ice until it is delivered to customers. If milk is carried to customers in cans rather than in bottles the cooling process should still never be omitted except in case of small dairies in the immediate vicinity of consumers under conditions which permit of the delivery of the milk before it has lost its animal heat. Even in such cases it is better to cool the milk before transporting it and to deliver it to the consumer at a temperature not above 60 F. for the apparent retention of the original animal heat is very deceptive, especially in summer and in warm climates. It is obvious that in the South, in the heated season, the milk may be kept approximately at animal heat by the high temperature of the atmosphere. It may therefore remain about at the body temperature until it sours.

In all cases it is important from a bacteriological standpoint that milk be cooled to at least as low as 45 degrees F. within fifteen minutes after being drawn and that it be kept at as low a temperature as practicable from that time until its delivery to the consumer. While on the farm milk should be stored only in a regular milk room properly protected against contamination with dust, filth, or odors, and kept in covered vessels. If milk is stored in a cold water tank the water must be changed frequently enough to prevent the development of bad odors in it. In order to get the best results from this system of cooling it is desirable to have the level of the water above that of the milk in the can. If ice boxes are used for cooling they should be thoroughly scrubbed at least once per week to prevent the development of molds and disagreeable odors. Under no consideration should ice be put into milk and milk should never be allowed to freeze in ordinary cans. It is also important from a bacteriological standpoint that night and morning milk should not be mixed.

If milk is delivered to consumers in bottles the dairyman should take the precaution of scalding the bottles before each refilling. It is of course commonly supposed that milk bottles are properly cleaned at the house of the consumer before being returned to the dairy. Different people, however, have different ideas of what constitutes proper cleansing and considerable difference has been observed in the efficiency of this work. Moreover in carrying the bottles from the consumer back to the dairyman there is the opportunity for contamination with dust and bacteria. Especial precautions must be taken in the use of bottles returned from houses in which infectious

diseases prevail, for the slightest carelessness may permit the contamination of such bottles and this would mean the probable infection of other individuals who might drink the milk from these bottles.

These dangers are largely avoided by the use of paper milk bottles, which have lately come somewhat into vogue. Two or three types of paper milk bottles have been suggested, one stamped in a solid piece out of pulp paper, and another rolled spirally like a paper mailing tube. The form is cylindrical, being of the same size at either end. The surface of the paper is covered with paraffine to prevent the milk from soaking through. These bottles in pint size cost about 40 cents per hundred or $3 per thousand. They are kept in a clean place before using and are to be used only once. They are of course much lighter than glass bottles and the trouble of collecting and washing are avoided. Paper bottles seem destined to come into more general use.

Care of milk kept on the farm.—Obviously the same care in general should be bestowed on milk which is kept on a dairy farm as upon that which is sold to customers. As should be obvious it is unnecessary to give any attention to perfectly fresh milk which is used at once for household purposes, but the milk which must be kept for the short period between milkings requires the usual attention to prevent it from souring prematurely or becoming contaminated. For the milk which is not to be kept longer than the period between two milkings a temperature of 60° is quite sufficient to prevent undue multiplication of bacteria. In fact as is shown in the chapter on the bacteriology of milk these micro-organisms do not begin to increase in milk for a few hours after it has been drawn unless the temperature of the milk is high and the amount of contamination unusually large. The souring of milk which takes place so soon in hot weather is not due to thunder storms or to other agencies than bacteria. The rapid souring of milk in warm weather is entirely due to the fact that relatively high temperatures are favorable to the development of bacteria. The micro-organisms which may gain entrance to milk, however, may cause other changes than souring. More or less rapid decomposition of the protein of the milk may be brought about and this leads to a very disagreeable change in the flavor and odor of the milk. In order to prevent these changes a temperature of 50° is desirable. In case of the occurrence of any infectious disease in the household of a dairy farmer strict precautions must be observed in preventing the patient or nurse from contaminating the milk which is used by other individuals, for if these precautions are not observed the milk may easily become the agent for carrying the disease to other members of the household and thus prolonging the expense and annoyance of quarantine and treatment as well as offering greater opportunity for the infection of the milk which is sold to regular customers.

The relationship between milk and digestive disturbances which may be produced in individuals who drink it is discussed in the

chapter on dietetics of milk, with special reference to infant feeding. In order to prevent the occurrence of digestive disturbances, especially in children, it is the common practice in the household to pasteurize or sterilize the milk even when it is believed to be reasonably healthful and sanitary. As mentioned in the chapter on pasteurization all disease germs and most of the bacteria which cause fermentation in milk are killed by heating the milk to a temperature of 140 degrees F. or higher for a period of ten to thirty minutes. The higher the temperature the shorter the time required for pasteurization. There are certain disadvantages which attach to pasteurization and sterilization of milk. If milk is boiled it acquires a cooked taste which renders it far less appetizing. Moreover its composition is considerably changed. Even pasteurization at temperatures too low to coagulate albumen produces some undesirable effects in milk. If the milk is not stirred during the process of pasteurization certain portions of it may be heated more highly than others and may thus acquire a cooked flavor. Moreover it must be remembered that in the process of pasteurization the lactic acid bacteria are destroyed. The elimination of these bacteria allow other still less desirable organisms, which produce decomposition of the protein, to multiply in the milk and render it far less suitable for food than it would be with the lactic acid bacteria present. Pasteurized milk if it is to be preserved for many hours after pasteurization must be kept at a low temperature in order to prevent the development of the bacteria which may not have been killed.

It is apparent from the previous discussion that the best method for securing pure sanitary milk for household use is to prevent the contamination of milk with bacteria or filth from the time it leaves the udder until it is consumed. If this is done no treatment of the milk is necessary except to keep it at a low temperature. Where any doubt exists, however, regarding the possible bacteriological examination of the milk it should be pasteurized at temperatures which will not give the cooked flavor and should then be kept at a temperature of 50 degrees F. or lower.

The same care mentioned as desirable in connection with milk intended for use in the household and on the dairy farm should prevail in the household of the consumer. It is undoubtedly true that the milkman is frequently held responsible for the premature souring of milk and for other unfavorable changes which are really due to carelessness in the handling of milk after the consumer has received it. It must be admitted that the consumer is responsible in this matter as well as the producer. Attention has frequently been called to the fact that however free the milk may be from bacteria and filth at the time when it is delivered, and however low the temperature of the milk, it will not long remain fit for human consumption unless it is handled in the proper manner. As already indicated, the bacteria in milk do not begin to multiply rapidly until several hours after it

has been drawn. By the time the milk reaches the consumer the bacteria are therefore ordinarily in a condition to begin rapid multiplication. This can be prevented only by keeping the milk at a low temperature until it is consumed. It is scarcely necessary to mention the fact that strict precaution should be observed in preventing the further contamination of milk in the household by dust or other filth or by the use of unclean utensils.

The present wide-spread fear of infection and digestive disturbances from the consumption of milk can be removed only by the organized cooperation of progressive dairymen in educating the public to a better appreciation of the food value of pure milk. In this connection after the consumer has had some experience in handling milk in the household according to modern sanitary requirements, he will the better appreciate the value of milk and will be more willing to pay a reasonable price for milk produced under sanitary conditions. The advance in the market price of milk in the average city during the past few years has not been as great as has taken place in almost all of our other food materials. Nevertheless the cost of milk production has increased greatly. This is due to the increased wages paid to farm labor, the greater value of cows, the increased price of land and the greater amount of labor necessary to produce, handle and deliver milk according to the requirements of the municipal boards of health. The public may therefore be reasonably expected to show a willingness to pay an increased price for milk which is known to be produced and handled under cleanly and sanitary conditions.

CHAPTER VII.

TRANSPORTATION AND SALE.

The condition in which milk reaches the consumer depends almost as much upon the care used in transportation as on the attention which it receives at the point of production. In small towns the problems of transportation are very simple. The producing farm is distant but a few miles at most from the consumer, and the milk is transported in wagons or carried by hand from house to house. In some tropical countries the problem is still further simplified by driving the cow or goat along the street and milking out the required amount before the door of the consumer. In country towns the milk is delivered so promptly after milking that it frequently still retains its animal heat when it reaches the consumer. At any rate it is delivered twice per day, and therefore the matter of cooling may be left entirely to the individual householder.

With the rapid development of our large cities the transportation of milk has presented problems which have exercised the ingenuity of producers, dealers and sanitarians alike. It requires 900,000 gallons of milk and cream daily to supply our 15 largest cities. In former years a much larger percentage of the milk was produced in the immediate vicinity or even within the limits of these cities. Recently, however, land values in such locations have become too high for profitable dairying, and as a result the milk has been transported from greater distances. The actual distance of the milk supply from our large cities varies from a few to nearly 400 miles.

This means a transportation period of twelve hours or more by railroad in addition to the time required for the distribution of the milk after it reaches the terminus in the city. Even if the best of attention were bestowed upon the milk at the producing farm it could not be kept sweet during a trip of 400 miles in an ordinary baggage car without refrigeration. The obvious problems in this connection have been met in different ways in different cities and will be discussed in the following paragraphs.

Milk is transported to large cities by steam railroads, electric railroads, steam vessels or by wagon. The percentage carried by these different means varies in different cities but on the whole steam roads carry the greater part of the milk. St. Louis, Cincinnati, New Orleans and Milwaukee are notable exceptions to this statement. In the case of these cities more than half of the milk produced is so near as to be delivered by wagon, in fact in New Orleans nearly all of it is so carried. Electric railroads carry large quantities of milk to cities, particularly Philadelphia, Cleveland, Detroit and Washington.

New York and San Francisco receive some of their milk supply by steamboat. The following table prepared by Ward shows the relative percentage of milk carried to cities by steam railroad (including electric railroad) and wagon:

Cities—	Carried by steam railroads— Percent	Carried by wagon— Percent
New York	88	12
Chicago	97	3
Philadelphia	90	10
St. Louis	43	57
Boston	80	20
Baltimore	78	22
Cleveland	84	16
Buffalo	85	15
San Francisco	55	45
Cincinnati	25	75
Pittsburg	90	10
New Orleans	14	86
Detroit	50	50
Milwaukee	25	75
Washington	57	43

In estimating the per capita consumption of milk in different cities a number of factors enter into the computation and the figures usually given are at best only approximately correct. As estimated by Ward for 1900 the per capita consumption in pints per day was as follows: New York .66, Chicago .75, Philadelphia .46, St. Louis .41, Boston 1.17, Baltimore .39, Cleveland .48, Buffalo .70, San Francisco .63, Cincinnati .61, Pittsburg .74, New Orleans .27, Detroit .70, Milwaukee .69, Washington .34. This represents not only the actual individual consumption but also the amount used in the manufacture of butter, cheese, ice cream, condensed milk, and oleomargarine.

In supplying milk to large cities one of the points which must first be settled is the rate of transportation charge. This varies greatly in the region of different cities and in some cases varies on different roads running to the same city. Such conditions have led to endless controversies between the dairy farmers, the railroads and the milk dealer. The rate charged for the transportation of cream varies from 5 to 10 cents more per can to twice the usual rate for milk. There is no uniformity in the matter. The only explanation offered by the railroads for charging a higher rate for cream is that the rate is based on the value of the product, not on the difficulty of transportation.

Milk Supply of New York City.

New York City consumes daily about 1,500,000 quarts of milk and cream. This is supplied by 200,000 cows and comes from dis-

tances varying from a few to 400 miles. It is estimated that 87 per cent of this supply comes from the State of New York and the balance from Pennsylvania, New Jersey, Connecticut and Massachusetts. There are about 550 milk shipping stations in the State engaged in forwarding milk to Greater New York.

According to Whitaker most of the milk sold in New York City is under the control of a few concerns which own the shipping stations in the country districts and are receivers, wholesalers and retailers at the same time. The number of stations owned by different corporations varies from one to 27, and ten concerns control one quarter of the whole number. The small dealer is gradually being put out of business and at present 90 per cent of the milk is handled by 125 dealers. Some of these dealers issue very stringent orders to the farmers from whom they buy milk. In one case at least it is required that the cows be healthy, the barns well ventilated, milk cooled to 38° F. immediately after drawing, no turnips, brewery or distillery grains, linseed meal or silage to be fed, milk room to be separate from the stable and night's and morning's milk to be kept separate.

In New York the shipping station is called a creamery and the size of the cans is 40 quarts. The farmers live for the most part within a radius of twelve miles from the milk station. Most of the dairy herds number 20 to 100 cows. The night's milk is supposed to be at a temperature not above 60° F. when delivered at the station in the morning. The milk is delivered at the station by 9 a. m., all sorts of wagons being used for this purpose. As a rule no attempt is made to furnish refrigeration for the milk on the way from the farm to the station. A canvas may be thrown over the cans in hot weather to protect them from the sun. If the farmers live ten or twelve miles from the station collectors may be employed to haul the cans, being paid by the milk dealers. The farmers own the cans in which they deliver their milk and clean cans are returned, the cleaning being done by the milk dealers. The milk is rarely loaded on the trains in the farmers' cans. At the simplest of the stations the milk is emptied from the farmers' cans, mixed, cooled and poured into the 40 quart cans for shipment. At some of the stations, however, the milk is clarified, pasteurized, blended and bottled or put in 40 quart cans. The bottling is done entirely at the creameries, about one-third being bottled and the other two-thirds being shipped in the 40 quart cans for supplying large customers. As indicated by Whitaker the low fat standard of 3 per cent in the State for milk makes it possible for the dealers to skim the milk and then standardize the product which they sell to exactly 3 per cent. Some of the producers have complained that an injustice is thus done them.

The milk stations are located from 2 to 6 miles apart along the railroad. The cans are returned dirty to the creameries and are there cleaned. They are often very filthy on returning but there are

good facilities at the ceameries for cleaning them.

A uniform type of car is used in shipping milk to New York City. It is shaped like an express car and built as a refrigerator car with only one compartment. There is a trap door in the roof for loading ice and ventilating apertures near the bottom. The railroads retain entire control of the cars and look after the icing and other details in the care of the milk enroute. The milk cars may be attached to regular accommodation trains or special milk trains may be made up in approaching Greater New York. At the small stations the train is stopped to load the milk directly from the creamery, while at the large stations a whole loaded car may be waiting for the train. The transportation rates are adjusted according to the zone system and are as follows: up to 40 miles 23 cents per can of 40 quarts, between 40 and 100 miles 26 cents, between 100 and 200 miles 29 cents, and 200 miles or over 32 cents. The rate on cream is 18 cents more per can than for milk. Nearly all milk trains running to New York reach the city between 10 and 11 p. m. There are no arrangements at the railroad terminals for the treatment of milk. The wagons are on hand at the arrival of the trains and haul the milk away to the different parts of the city.

Milk Supply of Boston.

In Boston distinction is made between car-milk and wagon-milk. About 80 per cent of the car-milk is handled by five wholesalers who are known as contractors. These men lease cars of the railroads, buy the milk in the country, maintain milk stations at the city terminals and sell the milk to distributors and retailers. The contractors have lately entered the retail field and appear to have an understanding with one another so that as Whitaker states two or three men can determine all important points in the milk business of Boston. The milk contractors also do a large cream business, but much of the cream supply of Boston comes from special creameries in Maine which began as butter factories but gradually drifted into the cream business. The can used in the milk trade of Boston holds 8½ quarts. It is supposed to hold 8 quarts after being battered with use.

The milk contractors of Boston pay a "milk" price for all that they sell as such and a "butter" price for the surplus. This arrangement has caused much controversy between the dealers and the producers. The contractors fix the city price of milk for the producers and maintain a scale of discounts for the transportation of each can according to the distance as follows: between 17 and 23 miles from Boston 6 cents, between 23 and 36 miles 7 cents, between 36 and 56 miles 8 cents, between 56 and 76 miles 9 cents. The discount increases one cent for each additional 20 miles. Some discontent has been caused by this plan for the reason that the farmers are unable to find out the cost of transportation. In 1905 the city price for milk

was 37½ cents per can. At first wooden plugs were used exclusively as stoppers for the cans. As these became checked with use it was found impossible to sterilize them properly.

Cans and plugs were returned to the farmers dirty and are supposed to be washed by them. This has formed a prolific source of trouble in the milk industry of Boston. The farmers claim that the cans are often in an unspeakably filthy condition when they are returned to them. It is asserted that consumers use the cans for slops, kerosene oil and every conceivable purpose. On the other hand complaint is made of the improper cleaning of the cans by farmers. The wooden plugs can not be perfectly sterilized without thorough boiling or steaming. Not all farmers' wives have facilities for such work. A reaction in favor of tin covers in place of the wooden plugs set in but it was soon found that the wooden plugs fit tighter and prevent leakage better. Moreover with wooden stoppers the cans may be conveniently stacked up on one another in the cars. At present the tendency is in favor of wooden plugs. In 1905 the farmers agreed to allow the contractors one half cent per can for washing them.

The system of certified milk has not been adopted in Boston. The only milk of special quality furnished to the city is delivered directly by large producers. Morning's milk produced near the railroad is taken to the cars without cooling but night's milk is supposed to be cooled to 50°F. before leaving the farm. The temperature of the milk as it arrives at the trains is sometimes taken by the contractor's agent and a record kept. The milk is loaded on the cars by the farmers.

The Boston milk cars are of a special type. The length is 48 feet inside measurement. Each car has an office in the center, a door at either end and eight closets 3 1-3x4 feet with two shelves carrying 3 tiers of cans each, or a total capacity of 720 cans. On some days additional cans are placed outside of the closets, making the number up to 1000. Each car carries two to four tons of ice at the start. The men in charge of the cars are in the employ of the contractors. As a rule the cars start at 5 or 6 o'clock in the morning and are 4 or 5 hours on the road.

About 50 cars of milk reach Boston daily. The trains are met at the station by the milk peddlers and retailers who hurry the milk away to their places of business. The peddlers mix the milk to produce a uniform quality and bottle it in their own establishments which are often somewhat defective from a sanitary standpoint. The contractors' receiving stations are fitted with the necessary apparatus for cooling and holding over surplus milk, and in some cases with butter and cheese making machinery.

Milk Supply of Philadelphia.

The milk consumed in Philadelphia comes from Pennsylvania, New Jersey, Delaware and Maryland. There are no special cars,

ordinary baggage or express cars being used. The cars are usually attached to passenger trains, and no attempt is made to refrigerate them. The farmers for the most part own the cans, which hold 40, 30, or 20 quarts, and vary greatly in shape. The milk dealers buy the milk at the city terminals and the farmers pay for railroad transportation by a system of tickets one of which is attached to each can. This plan has the advantage that the small and large producers are on an equal footing as far as the rate of transportation is concerned. The milk dealers, incorporated in an organization known as the Philadelphia Milk Exchange, fix the price paid to the farmers from month to month. There is no middleman between the dealer and the consumer in the milk business of Philadelphia. The dealer delivers the milk to the consumer.

Most of the milk trains start from 5 to 6 o'clock in the morning and arrive at the city between 7 and 9 a. m. Since the milk is thus only two or three hours on the road it is considered unnecessary to refrigerate it en route. The dealers, however, must have facilities for the mixing, bottling and cold storage of their milk. The great number of such establishments and the variation in their sanitary condition put a large amount of work and responsibility upon the milk inspector. Nevertheless there is certified milk sold in Philadelphia which contains as a rule only 500 to 1,000 bacteria per cubic centimeter.

Milk Supply of Other Cities.

The territory about Chicago is well supplied with railroads. The milk hauls are short, the longest being about 140 miles, and baggage cars attached to passenger trains are used for carrying the milk. For a few of the longer hauls an excellent type of refrigerator car is in service. Most of the milk arrives in Chicago from 9 to 11 A. M.

The immense quantity of brewery byproducts in St. Louis available as feed for cows makes it possible to maintain profitably about 8,000 cows within the city limits. This milk sells for somewhat less than that brought in by railroad. The longest haul of milk for St. Louis is perhaps 150 miles. Ordinary baggage cars are used and there is little need of rerfigeration.

The milk supply of Baltimore comes from dairies in Maryland and Pennsylvania within 50 miles of the city. The milk arrives from 7 to 9 A. M. There is great variation in the rates charged by the different railroads. There are but a few refrigerator cars in the milk service. For the most part baggage cars are used attached to local trains, and are cleaned from two to four times per month according to the season.

The Cleveland milk supply comes entirely from Ohio, within a distance of 60 miles, and arrives in the city either in the early morning or the evening. No refrigerator cars are used either by the steam or electric roads. Along the electric lines milk-stands are

erected at every crossroads. For the average haul the freight rate is 15 cents per 40-quart can.

All railroads make the same rate for shipping milk to Buffalo, even from a distance of 80 miles, 15 cents for a 40-quart can. The rate on cream, however, varies greatly on different railroads. Doane made a study of the milk supply in 29 cities in 9 southern States. In general it was found that the consumption of milk and cream is very small as compared with the northern cities. Throughout the South there is a large demand for ice cream and buttermilk. Much of the ice cream is made from whole milk, cream shipped from northern states or from condensed milk. In many localities there is more call for buttermilk than for sweet milk. There is not enough true buttermilk to supply the demand and consequently much of the so-called buttermilk in southern cities is skimmilk allowed to sour and then churned for a few minutes.

There are no regular milk trains in the South. Nearly all of the milk is produced within the city limits or on the immediate outskirts, and is easily delivered by wagon. As a rule the cows are milked very early in the morning and afternoon and the milk delivered at once to the consumers without any attempt at refrigeration. This plan is fairly satisfactory for the morning milk but the afternoon delivery is likely to suffer from the effects of heat. In such a simple system there is little unnecessary handling of the milk, but in midsummer the temperature of the air may be nearly that of the milk when drawn. Obviously therefore milk may be delivered almost at a body temperature although it is three or four hours old and nearly ready to turn sour. In hot climates the warmth of milk is not necessarily an indication of freshness.

In Richmond, Va., there are two large city milk depots which handle most of the milk. The farmers deliver to these dealers as soon as possible after milking. Here the milk is cooled at once and delivered to the consumers about 8 to 15 hours after its receipt by the dealers. In Memphis, Norfolk and certain other southern cities the conditions surrounding the transportation and sale of milk are about all that could be demanded. For the most part, however, the people need to be aroused and suitable inspection laws passed before a really good milk supply can be had.

Concentration and Cooperation in Milk Business.

From the above brief discussion it is apparent that the sanitary control of the transportation and sale of milk is a complicated problem. The health officers who are entrusted with the supervision of the city milk supply find it necessary to begin with the cows, examine the buildings and premises, note the method of milking and handling the milk, follow the milk on its journey to the city whether by wagon or train and inquire closely into the treatment which milk receives at the hands of the dealers and peddlers. If milk is allowed to become

filthy or infected before it leaves the farm no amount of care in transportation can protect the consumer Adequate refrigeration en route, however, will prevent the too rapid development of bacteria and thus keep the milk from souring before it reaches its destination. Neglect at any point in the transportation of the milk from the farm to the consumer endangers the healthfulness and keeping quality of the milk.

Milk should be cooled down to 50°F. or lower at the farm. If it is brought to the train without cooling refrigerator cars are required to prevent premature souring. If the milk has a temperature of 50°F. when delivered at the station and the railroad trip is not more than a few hours, refrigeration en route is not absolutely necessary. Such milk must be cooled at once, however, upon reaching the city. If the milk has been cooled at the farm and kept cool en route it is safe to omit refrigeration during the two or three hours necessary for delivery. It is not safe for the consumer to make any assumption regarding the care which the milk has received before it reached him, unless he is thoroughly familiar with the whole system and knows the methods of the farmers, the conditions of transportation and the dealer's plan of handling milk. Under any circumstances the householder should keep the milk cool from the time of its receipt till it is used. Some precaution may have been omitted. The milk may have been too much exposed to the sun in the farmer's wagon. It may have been shipped in a car without refrigeration and if so the temperature may have been 95°F. inside the car. An unusual amount of dirt may have gained entrance to the milk at the farm, or the dealer may have left the can open and thus allowed dust to fall in the milk.

The tendency of the times in all lines of business is toward concentration. It can not be denied that many advantages both from a business and a sanitary standpoint would accrue to the milk industry from still further consolidation and centralization. According to the present system of supplying milk to cities there are too many men concerned who are partly but not entirely responsible for the sanitary management of the business. When inspectors find samples of defective milk they may punish the man in whose possession it was found but he in turn may claim that the insanitary condition was due to the carelessness or ignorance of others. It seems desirable therefore that some one man or incorporated body of men should be ultimately and entirely responsible for the sanitary condition of the general milk supply of each city. The nearest approach to such a centralized system in the milk business is seen in New York where each milk dealer has complete control of the milk which he handles from the time when the farmer delivers it at the creamery till it reaches the consumer. The dealer has to assume the responsibility for the good condition of milk which he sells and he in turn tries to control by business contracts the conditions on the farms from which

he buys milk. This plan operates in a fairly satisfactory manner but there are frequent controversies between the farmers and the dealers. The farmers cannot learn the cost of transportation and therefore are never able to determine whether they receive fair treatment from the dealers.

Most of these troubles could be solved and an important step taken toward the procurement of an ideal milk supply for cities by establishing a general cooperative organization among the farmers who furnish milk to each city. This would involve the formation of a cooperative association of each community of dairymen, who would be represented by delegates in the council of the general federation of cooperative dairymen's societies in the city to which the milk is furnished. The farmer would then become a producer, dealer, distributor and retailer. He would control the milk in all its stages from the feed used in producing it in the cow through its transportation by railroad and wagon till it is placed in the icebox of the consumer. All controversies about prices and transportation would be eliminated, and the problems of the milk inspector would be much simplified.

One of the curses of the milk business in many cities is the part which grocerymen and small middlemen play. It is too often true that these men have no facilities for properly caring for milk. Milk is merely one of the many products which they sell and is the one to suffer most from lack of attention. If the farmers should organize on a cooperative basis so as to control both production and distribution the business would fully justify improvements to meet sanitary requirements all along the line. Better dairy buildings could be constructed, more attention given to the health of the cows, excellent milk stations established, modern refrigerator cars operated, and unexceptionable receiving stations and delivery wagons could be put in service in the cities. The inspector would then have but one concern to deal with. In case of a defective sample of milk being discovered it would at once become the duty of the cooperative association of dairy farmers to trace the sample to its origin and warn or punish the offender.

CHAPTER VIII.

REFRIGERATION

Cold is the best and most sanitary means of preserving all food products including milk. If no pathogenic bacteria are present, cold is all that is necessary to preserve milk in its best condition. If on account of the fear of infection the milk is previously pasteurized, cold must be applied to keep the milk in condition after pasteurization. Before discussing the methods of refrigeration in use we may briefly mention the physical and chemical properties of milk which determine its reaction to cold and the effect of cold upon it.

The specific heat of whole milk is about .94, of skimmilk .95, of whey .95 and of cream .87. Some differences are observed in the determination of specific heat by different investigators but according to Kasdorf whose results have been freely utilized in this chapter the specific heat of milk is so nearly that of water that for practical purposes it may be taken as the same. The expansion coefficient of milk is affected by the temperature. Between 40° and 60°F it is greater than that of water and the maximum density is reached at 26.5°F. The cohesion and viscosity of milk increase as the temperature is lowered.

The freezing point of milk is slightly lower than water, being about 31.5°F. The addition of water causes the freezing point to approach that of water. Skimming milk does not affect the freezing point. Advantage may be taken of this fact to detect the addition of water to milk. Parmentier found that the limit of variation of the freezing point of normal milk was 30.97° to 31.02°F. When eight volumes of water are added the freezing point is 31.9°F. The addition of borax or soda to milk also lowers the freezing point somewhat, and increasing acidity has the same effect. The freezing point falls .2°F. for every 24 hours the milk is held.

The application of cold to milk changes its physical and chemical properties. As a can of milk is frozen the solid constituents of the milk with the exception of the fat are gradually forced out so that the fluid portion contains more casein, milk sugar and ash than the ice milk while the latter carries a high percentage of fat. During the process of freezing the fat rises and is caught in the forming ice on the upper surface of the milk. In a partly frozen can of milk, therefore, the fluid portion has a higher specific gravity than the frozen portion. When a given quantity of milk is frozen into a solid block of ice the upper layer of the ice is composed almost entirely of fat while the center and lower portion contains the greater part of the milk sugar, casein and ash. When frozen milk is thawed out the

layer of fat at first remains separate and thorough shaking or stirring is required to restore a condition of fat emulsion such as is seen in normal milk. Flakes of fat and casein may appear in such milk and it is often impossible to get the fat distributed with perfect uniformity. The flakes are more conspicuous the longer the milk has been frozen. If milk is kept in an ice form for three months or more a considerable number of flakes appear after thawing and form a sediment. In addition to the flakes containing a large percentage of fat, irregular spherical granules are found in milk which has been frozen. These are apparently due to pressure in freezing. Milk which has been sterilized by heating before freezing can not be made to assume a normal condition after thawing. In this respect homogenized milk behaves in a very similar manner.

The extent and intensity of the disturbance in the relation between the different constituents of milk depends in large part upon the rapidity with which the milk is cooled and frozen. If milk is frozen in bottles or other vessels as rapidly as possible it readily assumes a normal condition after thawing. Milk in large cans, however, can not be frozen so quickly and after thawing shows neither the appearance nor the flavor of fresh milk. There is thus a distinct practical advantage in freezing milk in small vessels. The keeping quality of milk once frozen and thawed depends upon the care and cleanliness with which it was handled before freezing. The flakes of casein and fat mentioned above are readily dissolved by the application of heat after the milk has been in a frozen state for three weeks, less quickly after 4 to 5 weeks and not at all after 4 months. There is thus a practical limit to the time during which milk may be kept frozen.

Methods of Refrigeration.

The methods of refrigeration as applied to milk and its products include the use of cold water, ice, freezing mixtures, gravity brine system and various forms of artificial refrigeration involving the use of ammonia, carbon dioxid and other substances. The choice between natural and artificial means of refrigeration will depend in every case upon the local conditions.

Wherever available, cold water may always be used to help in the process of refrigeration. The extent to which milk or milk products may be cooled by water depends naturally upon the temperature of the water. Well water has a fairly constant temperature the year around. This ranges in most instances from 50° to 55°F and the water will cool milk down to within two or three degrees of its own temperature, or on an average 56°F. More often, however, the lowest temperature which can be produced in milk by cold water is 60°F. This means a lowering of 40 degrees from the body temperature and may be accomplished most cheaply by water at least in most instances. Then for cooling milk and its products to a temperature

suitable for long keeping recourse must be had to other sources of cold. Running water is not nearly so effective as melting ice for cooling purposes but there is economy in exhausting the effectiveness of the cold water before resorting to the more expensive methods of refrigeration.

Ice furnishes the simplest means of producing low temperatures in milk. It cannot be placed directly in the milk except in the form of ice-milk; otherwise it would be a form of adulteration and might contaminate the milk. Moreover ice melts rather slowly and its refrigerating effect is not exercised rapidly enough unless salt is added to it to make it melt faster. Ice may also be used to reduce water nearly to a freezing temperature after which the cold water may be applied to the refrigeration of milk. The refrigerating effect of ice is exercisd only when it melts. It then absorbs heat from surrounding objects. The temperature of the water resulting from the melting of the ice and salt mixture in an ice cream freezer is often below zero. The combinations of ice and salt are known as freezing mixtures.

The effectiveness of a system of refrigeration is judged largely by the rapidity with which it cools milk. On this point and also on the point of economy natural and artificial refrigeration may be best compared after both systems have been described.

Ice used alone melts too slowly and therefore exerts its cooling effect too slowly for farm, creamery or storage use. Freezing mixtures of cracked ice and salt, however, soon reach a temperature of zero F. They may be used on a small or large scale. The larger the proportion of salt the more rapid the melting. But it is necessary to practice economy in the matter, and while an ideal proportion would be two parts of ice to one of salt the common practice is to use one part of salt to ten or twelve of ice. The ice may be cracked and the brine pumped to the milk cooler by hand or by machinery according to the amount of milk to be cooled. A great variety of milk coolers of the flat or cylindrical type for the utilization of freezing mixtures have been put on the market in this country, England and continental Europe. Some of these coolers are double, the cooling process starting with cold water and finishing with brine. A saving is thus effected in the ice bill. A system much used in England includes an oak tank for holding the freezing mixture which is pumped to the cooler by hand. The brine returning from the milk passes through a copper coil in the upper part of the tank where it is cooled before being pumped back to the milk coils. In this machine salt and ice are used in the proportion of one to three. The mixture is kept stirred by a plunger connected with the pump.

In Berlin a cylindrical milk cooler has been devised using salt and ice in the proportion of one to six. An ice crusher is attached to one side of the brine tank, and the brine is pumped through the cooler so that it returns to the tank with the original force of the pump. This

agitates the brine and obviates the necessity of a copper coil and plunger in the tank.

In this country a modification of the brine apparatus has been devised by Cooper and is known as the gravity brine system. Cracked ice and salt in a tank produce an intensely cold brine which circulates through the cooling, refrigerating or freezing rooms as a result of differences of temperature at the two ends of the system. This system is therefore automatic and it is claimed that by its use a freezing room may be kept at a temperature of 15°F.

If desirable under any circumstances milk or its products may be placed in cans directly in the brine tank and removed after cooling. This involves the handling of cans and spilling the brine about the floor. It is therefore impossible to keep a dairy establishment in as good sanitary condition as by a system in which the brine is carried to the milk in pipes. The freezing brine is not always produced by mixing salt and ice. For example in Toselli's machine the freezing agent is a mixture of water and ammonium nitrate which causes a reduction of temperature to the extent of 40 degrees F. In an apparatus devised by Siemen a mixture of water and calcium chloride is used. This will reduce the temperature about 30 degrees F. Snow melts rapidly and therefore may be used in the place of ice wherever available in combination with some chemical. Among the chemicals used for this purpose we may mention sodium chloride, ammonium chloride, calcium chloride, dilute sulphuric, hydrochloric or nitric acid, nitrate of ammonium or potash, phosphate and sulphate of sodium, etc. Some freezing mixtures contain neither snow or ice but depend for their cooling effect upon the solution of a chemical.

One of the simplest forms of apparatus devised for cooling cream consists of a tank and a frame for holding the cream can which is revolved in the spring water or ice water in the tank. This apparatus is not very effective. Better results are obtained by the use of apparatus in which the milk or cream is allowed to trickle over a corrugated metal surface on the other side of which the freezing mixture is maintained either in a stationary or moving condition. Cooling apparatus using freezing mixtures with a direct current are less effective than those in which a reverse current is maintained. In machines with a direct current the freezing mixture and the milk flow in the same direction while in machines with reverse current they flow in opposite directions. By the use of a reverse current the greatest difference of temperature is maintained between the freezing mixture and the milk. If the reverse current is adopted a smaller quantity of freezing mixture and a larger cooling surface are required. For this reason the reverse current is utilized in cooling milk. A great variety of such coolers have been patented, their essential feature being a flat or cylindrical corrugated metallic surface over which the milk trickles while being cooled by the freezing mixture on the other side of the metallic surface. Some of these machines are

designed especially for cooling pasteurized milk or cream. They are made of all sizes to adapt them to a large or small business. The chief advantages of this system lie in the fact that the milk is cooled very rapidly on account of the thin layers in which it flows over the cooling surface, and the ease with which they may be cleaned. In some refrigeration plants use is made of a combination of the brine system and the expansion of ammonia, which is one of the chief physical principles utilized in refrigerating by the artificial methods described in the next paragraphs.

Artificial refrigerating apparatus depends for its effectiveness chiefly upon the two laws of physics that compressed air becomes colder by expansion and that fluids extract heat from surrounding substances in vaporizing. Several refrigerating systems have been devised to utilize these laws, such as the vacuum process, the compression process, water cooling towers, the absorption process, and the cold air system. Compression machines are the most important in the refrigeration of dairy products. These machines utilize sulphurous ether, methyl ether, carbon dioxid, sulphurous acid and ammonia, but chiefly ammonia. The ammonia machines in this country are of both the compression and absorption types, and the compressors operate under a wet or dry system. As described by Haven and Dean, "in wet compression some of the ammonia enters the compressor cylinders in a liquid state, the heat developed during compression being used up in converting the liquid into vapor, and consequently there is a saturated vapor at the end of the compression which has a boiling point corresponding to the condenser pressure. In this type no water jacket is required around the ammonia cylinder. In dry compression the ammonia entering the compressor cylinder is all in a gaseous condition, so that the heat developed during compression, if no water jacket is used, superheats the gas several hundred degrees above the temperature corresponding to the condenser pressure. A water-jacket surrounds the ammonia cylinder, however, and absorbs the heat, permitting cylinder lubrication."

Both the ammonia and carbonic acid machines are perfectly satisfactory in operation in mort instances but occasionally prove less certain in their results than the sulphurous acid machines. This is due to the fact that they operate under a pressure of 10 to 70 atmospheres, while the pressure in the sulphurous acid machines is only two or three atmospheres. Another advantage in favor of the latter machines is that the compressors require no special oiling since the sulphurous acid is of an oily nature. On the other hand these machines suffer from the disadvantage that from 20 to 60 per cent more energy is required for the same amount of refrigeration than when the ammonia machines are used. In the United States ammonia has practically replaced all other gases for purposes of refrigeration.

In the ammonia compression machines the ammonia is forced under high pressure into a system of coiled tubes where it is vaporized,

thereby absorbing the necessary latent heat from the surrounding material (brine, water or air). The gaseous ammonia is then drawn into a compressor where it is brought under pressure to a liquid state and then forced into a second system of coiled tubes known as the condenser where the heat is carried away by flowing water. The fluid ammonia is then carried back to the vaporizer and the cycle begins anew.

The absorption machines also use ammonia but the ammonia is vaporized under the direct action of heat rather than by the use of power. As described by Tayler these machines include apparatus for distilling, condensing and liquefying ammonia; a refrigerator, absorber, condenser, concentrator and rectifier; and pumps for forcing the liquid from the condenser into the generator. Haven and Dean describe the operation of these machines as follows: "The generator contains a solution of strong ammonia liquor in which the steamcoils are immersed. The ammonia in solution, having a lower boiling point than water, is partially vaporized by the heat from the steam-coils, leaving a weak solution of ammonia. The gas thus liberated passes through the analyser to the rectifier. Whatever water-vapor may have been carried along with the ammonia gas is condensed here and drips back into the generator. From the rectifier coils the gas passes into the condenser, and is collected in the receiver, from which it is expanded into the cooler or refrigerator coils. The gas from the cooler passes to the absorber and there meets the incoming weak liquor from the generator and is absorbed, forming strong liquor. The strong liquor is pumped through the exchanger into the top of the analyser and runs down over its pans to the generator."

The artificial refrigerating machines may be constructed on a large or small scale but are chiefly employed in cooling compartments for cold storage, which are called coolers if the temperature is 30° F. or above, holding freezers if 10° F. or lower and sharp freezers if zero to 20° below zero F. The absorption system is of little practical importance in the refrigeration of dairy products. It has been shown experimentally that the effectiveness of the compression machines is nearly proportional to the weight of the gas discharged, and that their ice-making capacity is about 60 per cent of their refrigerating capacity. The same machine may be used for making ice, refrigerating or both.

In one of the simplest compression machines for utilizing carbon dioxid in the place of ammonia the chief parts are a gasometer, pump, cooler, drier, condensing coil, and refrigerating tank. The carbon dioxid is drawn into the pump where it is liquefied, and the heat thus produced is absorbed in the cooler. The gas is then allowed to expand in the refrigerating tank and is passed back to the gasometer. Carbon dioxid unlike ammonia is non-corrosive to the piping. Moreover it is non-inflammable and has a high specific gravity, thus giving a high heat of vaporization. Compression machines for carbon dioxid must be operated under high pressure since it is difficult to liquefy the gas.

The energy required for operating with carbon dioxid is much more than is the case with ammonia. In large establishments the unit of refrigeration is the ton, or the refrigerating capacity of a ton of ice melting in 24 hour, which equals 284,000 British thermal units.

In most cases the relative economy will determine whether refrigeration is to be done with ice or machines. In the northern states if creameries or other dairy establishments are located near ponds or rivers it may be possible to store ice for a dollar or less per ton. At that price ice is cheaper than artificial refrigeration for a business of ordinary proportions. In all cases where ice is expensive and the amount of milk handled daily more than 15,000 pounds a refrigerating plant will prove a profitable investment. The advantages and disadvantages of mechanical refrigeration have been well summarized by Professor Erf in the following paragraph.

The chief disadvantages are that a large capital must be invested, the machines must be operated daily unless storage tanks are provided, operating expenses for coil, oil, ammonia and repairs are considerable, the excessive dryness in the refrigerators often causes great shrinkage in the products, there are risks for accidents due to breakage of machines and delay of repairs and lastly we have the expense of pumping water for condensing ammonia. On the other hand the important advantages of artificial refrigeration over natural ice are that there are no risks in securing cold when needed, little variation in the cost or refrigeration, better control of the refrigerator, the possibility of obtaining a lower temperature, a dried atmosphere and less liability of mold, less disagreeable work such as handling ice, better sanitation, no danger of contamination from impurities in river ice, better cream ripening and economy of space in the cooling rooms.

If the gravity brine system should be adopted, however, Cooper stoutly maintains that there would be "absolutely no risk to run in securing cold whenever needed. Any temperature may be practically obtained down to 15°F. The refrigeration would be under fully as good control and a more uniform temperature could be obtained than by the use of refrigerating machinery. The moisture in the atmosphere of the cold room could be carried at any temperature desired and under as good control as with the mechanical system. The amount of disagreeable labor required, should an ice crusher and ice elevator be used, would be very small indeed. The cold room can be kept as clean as with any system. Impurities in the ice would have no influence on the air of the room for the reason that the air does not come in contact with the ice."

It would lead us too far from the purpose of this volume to go into details regarding the construction of ice houses or refrigerating plants, the materials to be used or methods of securing proper ventilation, absorption of moisture, insulation and circulation of cold air. These matters belong to the field of the architect and builder. In the follow-

ing paragraphs we call attention to some of the special applications of refrigeration to milk and its products.

The creaming of milk is greatly influenced by the temperature. A richer cream is obtained under a high temperature and the process takes place more rapidly. On the other hand the rapid souring may give a bad flavor to the cream and the premature curdling of the milk may prevent all of the fat globules rising to the surface. These facts induced the use of ice or some other form of refrigeration in the creaming of milk. It has been found that the lower the temperature, within reasonable limits the larger the amount of cream obtained and on this account refrigeration in the field of dairying was first applied to the ripening of cream and the creaming of milk. These matters are discussed in the chapter on Milking and handling of milk.

Ideal refrigeration requires that the milk be cooled down as soon as possible to a temperature at which lactic acid bacteria can not grow. If cream is to be used as such rather than for making butter it retains its aroma and flavor longer the lower the temperature provided the cream is not frozen. For this purpose 39°F. is a good temperature. Usually milk is held at 50° F. but 40° F. is better. Skim milk direct from the separator should be hept at the same temperature.

Frozen Milk.

Since 1888 experiments have been made in freezing milk to preserve it in a fresh condition. In 1894 it was shown that by adding a certain proportion of frozen milk to a can of milk and packing it in sawdust the whole mixture could be kept fresh for two or three weeks. At the earlier date Guerin's plan of freezing milk at a temperature of 2° F. below zero was adopted by a large dairy which furnished milk for Paris. In 1893 and 1894 a Danish engineer patented a scheme for freezing milk and made application for many other patents which were not granted. The Casse system was adopted by a Danish dairy company which furnished daily 30,000 pounds of milk to Copenhagen. Their plan was to freeze milk in cakes weighing about 25 pounds and place them in cans holding about 500 pounds of milk. One cake was placed in each can at night and the next morning the cans were filled with fresh milk and closed air-tight before shipping. When treated in this manner the milk kept in good condition for several weeks being drawn at will. The contents of the cans were thawed out by placing them in vessels surrounded by hot water coils. It is claimed that the currents thus produced mixed the constituents of the milk and preserved the original flavor and composition. Butter made from such milk, however, was unsatisfactory. In 1898 an establishment near Zurich began to furnish 10,000 pounds of milk-ice daily to that city. It has been found to keep nine days, sweet and unchanged. In Copenhagen the demand for milk-ice has increased and the public prefer it to other milk for the reason that the chilling as soon as possible after milking preserves the original aroma and hinders the

growth of micro-organisms. It is of advantage to dealers since surplus milk can be stored for some time and used as needed.

In a chemical study of frozen milk Siegfeld found that the upper portion of the block of milk-ice contained 8.45 per cent of fat and the lower portion 2.11 per cent. The percentage of total solids in the milk-ice increased toward the center of the cake. When skim milk was used the outer portion of the frozen cake contained 7.03 per cent of solids and the central part 15.9 per cent. The freezing of cream resulted in decreasing the time required for churning. Farrington found that when 25 per cent of a sample of milk was frozen the fat content of the liquid was about .5 per cent higher and of the ice about one per cent lower than that of the original sample. When 40 to 50 per cent of the sample was frozen there was no great difference in the fat content of the liquid and iced portions.

In Germany the repeated application for patents on processes for making milk ice has led to legal definitions according to which "cold milk" means milk to which milk ice has been added, and "milk ice" means frozen milk. Casse's system has been introduced most extensively in Denmark and Sweden. Opinions differ widely as to the adaptability of the method and the results obtained by its use. One great objection to any method in which half of the milk is frozen is the cost. It requires about 140 calories to freeze 2½ pounds of milk and of this number only 80 can be saved in melting while 60 are entirely lost. The only way by which a saving may be made is to reduce the amount of frozen milk added to each can. A plan was devised by Helm to meet these requirements and has been put into use in several German cities. The milk is first pasteurized, then cooled to 35 F. after which varying quantities of milk ice are added according to the distances to which it is to be shipped. It was soon found that when milk was pasteurized and then refrigerated with milk ice one bad result of pasteurization became apparent. As a result of pasteurization the lactic acid bacteria are destroyed and this allows the putrefactive organisms to decompose the milk albumen. Such an outcome may be prevented by adding a small quantity of pure cultures of lactic acid bacteria after the milk has been cooled.

As already indicated one of the serious objections to the commercial adoption of the milk ice system lies in the fact that in freezing the uniform distribution of the different solid constituents of the milk is disturbed. The larger the vessel in which the milk is frozen the greater the variation in the composition of the different portions of the milk. On this account it is obviously desirable to use small cells or cans for freezing. This idea, however, should not be carried too far. About 6 inches is the smallest diameter practicable for freezing. The outside of a cylinder of milk is frozen much more rapidly than the center. This is due to the fact that the milk solids accumulate in the center as the freezing proceeds. Bernstein therefore devised a freezing cell in which the central part was occupied by a metallic

tube. In order to insure the retention of the normal composition in all parts of the milk the freezing cell is made heavy enough to hold the milk ice at the bottom of the vessel of milk to be cooled. As the milk ice melts the temperature differences keep up a constant circulation of all parts of the milk.

It has been found possible to obtain frozen milk in the form of milk snow by freezing a spray of milk on the outside of a cylinder from which the frozen milk is constantly scraped off. This prevents any abnormal distribution of the constituents of the milk. Cream may be frozen in the same manner but this method of handling it has not found commercial acceptance. In Finland the plan has been adopted in at least one town. The cream can is placed in a freezing mixture immediately after separation and the cream promptly freezes. More cream is added after each milking until the can is full, the process requiring a week or more for each dairyman. Frozen cream possesses a striking resistance to changes of temperature and therefore stands shipment well.

Cold Storage of Butter.

There is some difference of opinion regarding the proper temperature for the cold storage of butter, but the present tendency is decidedly toward the use of very low temperatures as compared with those previously in vogue. At first a temperature of 35° to 40° F. was considered satisfactory. This degree of cold was found sufficient to keep butter in a fairly good condition for two or three months. But the standards of efficiency for cold storage are higher and the requirements are becoming more severe. Perhaps the majority of dealers consider 20° F. low enough for butter. It has been found, however, that at zero or below butter keeps well for 9 months or more. Both flavor and quality are retained and the loss in weight is practically null. For long storage of butter Cooper recommends a temperature of 12° to 15° F. It may be found that the grain is injured by storage at temperatures about the zero point, but the danger from exposure to air will be much less than at higher temperatures. The desirable aroma and flavor of butter may best be preserved by applying low temperatures and protecting from the air.

Cold Storage of Cheese.

Formerly cheese was cured and stored at ordinary temperatures but about twenty years ago cold storage began to be applied to this product. The whole problem of cold storage of cheese has been most thoroughly investigated by the Bureau of Animal Industry and the experiment stations in Wisconsin and New York. A preliminary investigation by Babcock and Russell in Wisconsin showed that in the ordinary cheese curing rooms there is too great a variation of temperature, often running as high as 90° F. and in one case to 104° F. In the experiments in curing rooms with regulated temperature it was soon found that the rate of curing is proportional to the temperature, the higher

the temperature the more rapid the curing. In every case cheese cured at high temperatures were inferior to those held below this point. Both the flavor and texture suffered from the high temperature. The loss in weight was found to be greater at high than at low temperatures, and while the cheese reached maturity more quickly its commercial period was shorter. In the experiments of the Bureau of Animal Industry when temperatures of 40°, 50°, and 60°F. were compared the loss of moisture was less at low temperatures, the quality of the cheese was better and the cheese kept longer. A temperature of 40°F. proved better than 34° or 28°F. as determined by a careful scoring test. The combination of a low temperature and the use of paraffine reduced the loss in weight to a minimum.

Condensed Milk and Milk Sugar Obtained by Freezing.

The customary method of manufacturing condensed milk requires the application of heat to drive out the water. It is less costly, however, to freeze out the water than to evaporate it by the use of heat. As shown by Kasdorf it requires 600 calories to desiccate 2½ pounds of milk by heat and only 80 calories to freeze it dry. Moreover when heat is applied the casein is denatured and the flavor of the product is changed. For several years therefore attempts have been made to produce condensed milk by the use of artificial refrigeration. Of the devices proposed for this purpose that of Gürber is perhaps the best. According to this plan the milk is frozen in a centrifuge in such a manner that the processes of freezing and thawing are made parts of one operation, and the milk ice while in process of formation is forced to give up its solid parts under centrifugal action. Gürber has improved his method by the use of an apparatus in which the milk is conducted over the outside of a cylinder cooled from the inside. The solids of the milk are thus separated out according to the principle of the separation of chemicals from solutions by freezing.

Some attention has been given to the problem of separating milk sugar by means of refrigeration. A device perfected by C. Schmitz may perhaps be used for this purpose. Fluids containing different substances are frozen by being thrown as a spray into chilled air. A number of different substances are thus formed such as salt crystals, ice crystals of pure water, etc. The different bodies will have different specific gravity and may be separated by blasts of air.

It has already been stated that in freezing milk suffers a disturbance in the distribution of its constituents. The upper layer when frozen contains more fat than normal milk, while the other solid parts of the milk become concentrated in the still liquid portion. Seyboth has taken advantage of this fact in the preparation of hygienic infants' milk of any required composition. Special cans have been devised in which the desired percentage of fat or other solids in the milk may be obtained by regulating the process of freezing.

The refrigeration of milk during shipment is a rather expensive process. A number of refrigerating milk cans have been devised some with a central cylinder containing ice and with or without insulation. For long shipment the can may be placed in a cold brine tank in the car. Square cans pack more closely than cylindrical cans. Some insulating material may be thrown over the cans. Better results will of course be obtained by the use of refrigerator cars. The only objection to them is the expense connected with their operation. In the United States nearly all refrigerator cars are cooled by ice or cold brine. Their extensive use for the shipment of meat and fruit is well known to all, and in some cities it has become desirable or even necessary to make use of them for the shipment of milk. Their use insures the receipt of the milk at the city terminal without deterioration.

CHAPTER IX.

PASTEURIZATION AND STERILIZATION OF MILK.

On account of the fact that it is impossible to obtain milk on a commercial scale free from bacteria, attempts have been made to use chemical antiseptics and to apply heat in order to render milk sterile or nearly so after it has been drawn. There are more or less serious objections to the use of all chemical preservatives in milk and accordingly more attention has been given to the perfection of methods of pasteurization. Soxhlet was the first to apply pasteurization to the treatment of milk, especially for the use of infants. His recommendation of this process was made in 1886. In 1889, experiments in pasteurization were begun in America, and since that time the procedure has gradually gained in favor, although many objections have been raised to it from various standpoints. In 1892, sterilization of milk in tenement houses in New York was adopted and at present it is estimated that about 25 per cent of the total milk supply of New York is pasteurized. About one-third of the milk supply of Boston is subjected to commercial pasteurization. Pasteurization in bulk is generally practiced in Denmark, Germany, France, and other countries of Europe. This practice is so widespread in continental Europe that sanitary officers have been led to doubt the accuracy of American investigations regarding the transmission of infectious diseases, particularly diphtheria and scarlet fever in milk. Where milk is generally pasteurized before use it is obviously impossible for it to be an important vehicle in the transmission of these diseases.

Distinction has been made between pasteurization, which usually means the heating of milk to a temperature of 140 to 185° for a variable period, and sterilization, which means the application of heat at the boiling point or above for a shorter or a longer period.

The first matter for consideration in pasteurization is the choice of apparatus. If it is merely desired to sterilize milk as thoroughly as may be for household purposes without special regard to the maximum temperature, the milk may be placed in any clean cooking utensil and boiled over a fire for a short time. It is ordinarily not necessary to boil the milk but a few minutes since the boiling temperature destroys all bacteria except spores and these may not be destroyed even in a longer period of boiling. In pasteurization for household purposes, the methods may be quite inexact. Milk is placed over the fire in a cooking utensil and raised nearly to a boiling point or to a temperature ranging from 170 to 185°F. after which the milk is removed and allowed to cool. More exact household methods consist in sterilizing the milk in cans or jars placed inside of another utensil containing

water which is heated to the required temperature. If the milk container is placed in another vessel containing water, it is best to have a perforated false bottom so that the milk is entirely surrounded by water. The different portions of the milk are thereby heated more uniformly.

The requisites for successful pasteurization have been well stated by C. D. Smith. The milk to be pasteurized should be fresh from the cow and should be handled in as cleanly a manner as possible in order to prevent the entrance of spore-bearing bacteria which are largely derived from sources outside of the cow. The milk should be brought rapidly to a temperature of 140 to 185° F. and kept at that temperature for 5 to 20 minutes depending on whether the high or low temperature is adopted. It is somewhat unsafe to heat milk above 160° F. since objection may be raised to a cooked flavor. All apparatus used in the pasteurization of milk must be kept scrupulously clean and milk must be brought down to a temperature of 50° F. immediately after pasteurization and held at that temperature until it is used.

In pasteurizing milk on a large scale, the objection has been made against an intermittent form of pasteurizer that it requires too much time and is therefore an expensive apparatus. A number of forms of intermittent pasteurizers have been devised but, as stated by Russell, they must all be efficient in operation, easy to clean and sterilize, simple in construction, economical in use, and safe from reinfection. An effective combined pasteurizer and cooler was devised by Russell and was found to give excellent results in destroying pathogenic and other bacteria in milk and in prolonging the keeping property of the milk without producing any disagreeable effects in it.

Russell and others have made an extended study of the efficiency of continuous flow pasteurizers. These machines possess the great commercial advantages of easy operation and great capacity. The milk flows over heated surfaces or through heated pipes in a continuous stream and in some of the most improved types the pasteurized milk is carried back over the same course along which it entered so as partly to warm the fresh milk entering the machine. A great disadvantage of continuous pasteurizers is that the milk is subjected to heat for a very short period. In Russell's experiments with a continuous pasteurizer it was found that the milk passed through the apparatus in about 15 seconds when the machine was running at full capacity. Some of the milk, however, was retained in the machine for 30 or even 45 seconds. The time exposure to heat was increased to 70 to 100 seconds by half closing the inlet pipe, thus making the rate of flow about 1,000 lbs. of milk per hour. It is obviously necessary that the milk should be subjected to the required temperature for a definite period of time if pasteurization is to accomplish the purpose of destroying a large portion of the bacteria in milk. There is no question that the tank or intermittent pasteurizer is more efficient

in this respect than the continuous pasteurizer, but the prolonged retention of the milk in the machine renders the apparatus impracticable for use on a large scale. Under proficient supervision and with a proper limitation of the rate of flow the continuous pasteurizer may be operated so as to give satisfactory results on a commercial scale.

Effect of Pasteurization on the Biology of Milk.

The chief purpose of pasteurization being the destruction of pathogenic and harmful bacteria in the milk, it is of prime importance to inquire how effectively this purpose is accomplished. In the use of a continuous pasteurizer tested by Russell, it was found that the number of bacteria per cubic centimeter after pasteurization ranged from 5,000 to 18,000 as compared with a range of 125,000 to 965,000 per cubic centimeter of raw milk. These figures are for the winter conditions. In summer the range of bacterial content after pasteurization was 2,900 to 1,000,000 per cubic centimeter as compared with 1,000,000 to 60,000,000 in raw milk. It is apparent from this test that only a certain percentage of the bacteria present in milk are destroyed by pasteurization in the continuous machine and if the milk is not heated to a temperature of 160°F. it may contain virulent pathogenic bacteria after pasteurization.

Rogers called attention to the fact that pasteurization to be considered efficient should destroy practically all of the bacteria in the vegetative stage. This result is accomplished by the application of a comparatively high degree of heat for a short time or by a lower temperature for a longer period. In intermittent machines the milk is usually held at the chosen temperature for from 15 to 30 minutes.

The tubercle bacillus has been taken as a standard for determining the efficiency of pasteurization. When milk is properly pasteurized and agitated at the same time so that no film is allowed to form on the surface, it has been definitely shown that tubercle bacilli are destroyed by an exposure for 15 to 20 minutes at a temperature of 60°C. (140°F.). In ordinary practice, however, it has been found safer to subject the milk to a temperature of 68 to 71°C. In continuous pasteurizers some experiments have shown that a temperature of 80° to 85°C. is required to destroy tubercle bacilli. A great amount of attention has been given to a study of the thermal death point of the tubercle bacillus in commercial milk. The results obtained by different investigators have varied somewhat depending upon the kind of apparatus used and the care with which all conditions are controlled. Russell and Hastings found that a temperature of 60°C. for 10 minutes was sufficient to render tubercle bacilli nonvirulent but not to destroy their vitality entirely. A temperature of 60°C. for 5 minutes was not sufficient to attenuate the tubercle bacillus while the same temperature or 140°F. for a period of 20 minutes destroys the tubercle bacillus absolutely without injuring the creaming or other properties of the milk.

In the extensive experiments of Rogers on the bacteria in pasteurized milk it was found that milk pasteurized in a continuous machine at a temperature of 185°F. showed a reduction in bacterial content from 10,000,000 to 500 per cubic centimeter. After 12 hours the peptonizing bacteria in some samples of the pasteurized milk multiplied rapidly and the milk was usually curdled within 48 hours with the development of a disagreeable flavor and odor. In a few samples the lactic-acid bacteria resisted pasteurization and multiplied so rapidly after 24 hours that the peptonizing bacteria were unable to develop further. In most cases the bacteria in the pasteurized milk developed so slowly that no change in flavor was noted until 96 hours after pasteurization.

It has to be recognized that pasteurization is only partly effective in destroying the bacteria in the milk and furthermore that it is impossible to render milk absolutely sterile even by boiling for a long period. The boiling temperature will of course destroy all vegetative forms of bacteria but spore-bearing forms will resist this temperature and will develop later in the pasteurized milk. The greatest danger connected with pasteurized milk is the feeling of false security which it gives to the ordinary milk consumer. The idea seems to prevail quite generally that pasteurized milk is sterile and must be a perfectly safe food until consumed. This, however, is far from being the case. As already indicated, pasteurization is more likely to destroy the lactic-acid bacteria than the peptonizing bacteria. For this reason the peptonizing bacteria have a free field in which to develop after the milk has been pasteurized. The absence of lactic-acid bacteria prevents the development of an acid which would check the growth of peptonizing bacteria. The latter, however, are the micro-organisms which cause nearly all of the disgusting flavors or odors in milk and may produce dangerous toxins and other bacterial products. Pasteurized milk, therefore, should receive the same treatment after pasteurization as raw milk. In other words, it must be brought down as soon as possible to a temperature of 40 to 50°F. and kept at that temperature until used. Moreover, the exercise of care in preventing contamination of pasteurized milk is of more importance than in the case of raw milk.

Effect on the Physical Properties of Milk.

The pasteurization of milk has the effect of diminishing its viscosity for the reason that the fat globules, which in normal milk have a tendency to occur in irregular clumps are distributed more uniformly after pasteurization. If milk contains calcium chlorid the coagulation point of the casein is reduced as a result of pasteurization, but the time required for coagulation is lengthened. The effect of pasteurization upon the fat globules and upon the cleanness of skimming has been found to vary considerably depending upon the conditions of pasteurization. If milk is put under considerable pressure in the

pasteurizer the loss of fat in the skimmed milk in running through a separator is greater than when no pressure was used in the pasteurizer. The slight coagulation of casein which may occur in heating milk is apparently due to a change in the structure of the casein combined with the action of small amounts of acid formed from lactose when milk is heated at high temperatures.

Since the relative consistency or viscosity of cream is somewhat affected by pasteurization a number of experiments have been made, particularly by Babcock and Russell for the purpose of restoring the consistency of pasteurized cream. It was found that the viscosity of pasteurized cream could be restored by adding freshly slaked lime in solution. The lime solution was prepared in a solution of cane sugar in water. No sanitary objection can be raised to this process since lime is a normal constituent of milk and the amount added for restoring viscosity rarely exceeds four parts per 10,000. Finely divided egg albumen, tricalcium prosphate and blood fibrin were tested for the same purpose with poor results. It was found, however, that one part of rennet per 200,000 parts of pasteurized cream was sufficient to restore the consistency of the cream within a few hours.

It has been found that milk heated too long or at a too high temperature will not afterward coagulate under the action of rennet. In general the completeness of coagualtion is somewhat hindered by pasteurization. If milk is pasteurized after a slight acidity has already developed, for example 0.2 per cent, there is danger of the milk coagulating during the process of pasteurization. There seems to be little objection which can be raised to pasteurization from the standpoint of butter making since butter from pasteurized milk ordinarily scores as high as that from unpasteurized milk under the same conditions.

Effect on the Chemical Properties of Milk.

In experiments by Rettger it was found that sulphid was given off when milk was heated to a temperature of 85°C. This was apparently hydrogen sulphid due to the partial decomposition of the milk proteids. The amount of sulphid thus liberated is very small but is sufficient to be detected by lead acetate or potassium permanganate. The extent to which the proteins of milk are affected in their essential composition is not sufficiently understood. A number of investigators have found that the lecithin content of milk is considerably reduced by pasteurization. In nearly all cases the acidity of milk is also diminished by heating.

Effect on Digestibility.

The literature relating to the digestibility of pasteurized milk is very extensive. For the most part it relates to the use of pasteurized milk for the use of children and to the supposed harmful results of using pasteurized milk continuously. The extensive literature on this subject, however, is open to the objection that the care of the

milk after pasteurization was not taken into consideration. In the few careful experiments which have been made with calves, dogs, and children, it appears that no injurious changes have been definitely shown to take place in milk as a result of pasteurization.

The advantages and disadvantages of pasteurization have been well summed up by Rosenau. In the first place, it has been claimed that pasteurization promotes carelessness on the farm and dairy. The idea underlying this objection is that if the dairyman knows that his milk will be pasteurized after reaching the city or in a central pasteurizing plant, he is less likely to use the necessary precautions regarding the sanitary handling of his milk. This possible objection may be overcome by suitable inspection of dairy premises and the enforcement of sanitary regulations upon these premises. If the larger part of the milk supplied to cities is to be pasteurized it is of great importance that all contamination after the milk has been drawn should be reduced to a minimum in order to avoid the entrance of spore-bearing peptonizing bacteria into the milk. The objection that pasteurized milk is less digestible than raw milk is not well founded since there are no reliable experiments indicating that the digestibility of milk is affected by pasteurization. The claim that pasteurized milk causes scurvy or serious digestive disturbances is in most cases based on careless observation of cases in which the milk after pasteurization was allowed to become contaminated or was not kept at a sufficiently low temperature to prevent the development of peptonizing bacteria. The most serious objection to pasteurization is that it destroys the lactic-acid bacteria which are the only safeguard against the development of more harmful species of bacteria in milk. The only means of preventing this unfavorable result is to keep pasteurized milk at a low temperature. The campaign of education along this line is absolutely necessary in order to prevent milk consumers from entertaining the comfortable assurance that pasteurized milk can not possess harmful properties. It is quite true that pasteurization does not render milk completely sterile but there is no known method of accomplishing this result except that of repeated boiling corresponding to the method of fractional sterilization of nutrient media in bacteriological research. This is obviously an impossible procedure for adoption on a commercial scale since it would be very expensive and the flavor of the milk would be greatly altered. The objection that pasteurization increases the cost of milk is of very little weight since it is certainly a cheaper method of rendering milk safe than any other which has yet been devised. It must be recognized by milk consumers that the production of safe and sanitary milk answering the requirements of municipal health officers is accompanied with more expense than was necessary for the production of market milk ten years ago. In order that milk producers may take a more lively interest in the production of strictly sanitary milk it is first necessary that the consumer should recognize that there are different grades of milk

varying in cleanness and wholesomeness and consequently varying in their real value. So long as consumers are not willing to pay somewhat more for clean, healthy, and wholesome milk than for ordinary unguaranteed milk the producer can not be expected to devote his time and energy to scuring a superior article which must compete with an inferior grade of milk on the market for the same price.

In order to overcome the objections which in many cases have been found to hold against pasteurized milk it seems most desirable, as has already been suggested by various sanitary officers, that a central pasteurizing plant, preferably under private management, be established in every city where all milk which can not be otherwise certified shall be pasteurized before being placed on the market.

Pasteurization by means of electricity is discussed in connection with the bacteriology of milk.

CHAPTER X.

PRESERVATIVES IN MARKET MILK.

The action of chemical preservatives in hindering the development of bacteria and preventing decomposition of food products has long been a matter of common knowledge. A list of preservatives which have been used in attempts to improve the keeping properties of market milk is, however, not very large. It includes formaldehyde, boric acid, borax, hydrogen peroxid, benzoates, salicylates, sodium carbonate, saltpeter, chromates, etc. In recent years, however, nearly all of these preservatives except formaldehyde have been discarded as far as milk is concerned. The general question of the use of preservatives in food products is at present prominently before the people and the effects of these preservatives are being carefully studied in order to secure a solid scientific basis for rulings under the new food and drug legislation. Without admitting that the use of preservatives is harmless or justified in the case of any food it is particularly objectionable in the case of milk for the reason that this product may be obtained strictly fresh twice daily and may be delivered to the customer in a perfectly fresh and wholesome condition even from a distance of 300 to 400 miles by the simple observance of rules of cleanliness and the use of refrigeration. Clean milk kept cool will not sour or undergo other harmful changes within the period of time in which it may reasonably be kept in the household before using.

It may be stated in advance of the special discussions to be given to different preservatives that as yet we know no chemical substance which is at the same time germicidal and without harmful effects on the living cells of the body. It is well also to bear this undoubted fact in mind considering the possible use of proprietary preservatives, for almost without exception these preservatives contain the usual chemical substances which are known as preserving agents. Although being sold under trade names they are nevertheless no more harmless than salicylic acid, borax, formaldehyde, and the other materials of which they are composed when used in a pure state. In fact, there are more serious objections against proprietary preservatives than against pure chemical preservatives for the reason that their composition is more variable and excessive doses of one or the other of their constituents may, therefore, be taken in drinking milk.

Formaldehyde.

Formaldehyde is an oxidation product of methyl alcohol and bears the chemical formula H. COH. The commercial formalin or formol is a 40-per cent solution of formaldehyde gas in water. Formaldehyde has been used as a disinfectant and germicide for about 20 years.

In surgical operations it has not given the satisfaction that was at first expected from it on account of its irritating effect upon the tissues. Its use as a preservative of foods began about 1895. It is now extensively used in the preservation of milk.

Milk containing 1 part of formalin to 5,000 parts was found by Merkel to keep sweet for 100 hours at a temperature of 25°C. and for 50 hours when containing 1 part of formalin in 10,000 parts. The same investigator noted that some of the casein was precipitated in flakes and that the presence of formalin interfered with the digestion of the milk proteids. Similarly Rideal found that milk containing formalin at the rate of 1 part in 10,000 would remain fresh for 7 days. On examining market milk this author found that one-half pint of formalin had been used in the preservation of 17 to 18 gal. of milk. No artificial flavor or smell appeared in milk treated with formalin even after it had been boiled. Young found, as a result of an examination of all available literature on the subject of formaldehyde, that when this substance is used as a preservative it tends to lower the nutritive value of milk and to interfere with the digestive processes. In the proportion of 1:1,000, formaldehyde exercises a decided germicidal action. Its germicidal effect is even noticeable when used in milk at the rate of 1 to 100,000. Rivas claims that when used in the proportion of 1:50,000, formaldehyde disappears from milk within 24 to 72 hours and that it begins to disappear within 6 hours. If formaldehyde is added to milk in higher proportions the disappearance of the preservative is very slow.

The direct effect of formaldehyde upon animal tissues is to cause a considerable hardening as a result of the extraction of water. In a series of experiments by Rideal and Fullerton on kittens, rabbits, and guinea pigs, it was found that formaldehyde in the quantities ordinarily used in the preservation of milk had no striking effect upon proteid metabolism as shown by the weight of the animals. In these experiments formaldehyde was used at the rate of 1 part in 50,000.

The proteids of milk are undoubtedly changed by means of the presence of formalin and relatively large quantities of formalin are necessary to prevent harmful changes taking place in market milk. The antiseptic power of formaldehyde, however, is considerably greater than that of boric acid, in fact 50 times greater according to the investigations of Cochran. This writer found that milk treated with formaldehyde at the rate of 1 part to 10,000 underwent artificial digestion in about the same time and manner as milk untreated. Even small amounts of formaldehyde, however, lessen the coagulability of casein with rennet and interfere with the natural digestion of casein. In experiments by Trillat it was found that the digestibility of untreated casein was from 5 to 30 per cent greater than that of milk treated with formaldehyde in varying amounts. From these experiments it was concluded that formaldehyde is harmful or even dangerous for infants.

The experiments of Price with formaldehyde and milk in vitro indicated that this preservative when used at the rate of 1 to 20,000 will keep milk fresh for 40 hours. Even when used to the extent of 1 to 2,500 parts the formaldehyde appeared to have no effect on the activity of fresh enzyms, rennet, pepsin, or other digestive ferments. Price concludes, therefore, that formaldehyde may be added to milk in sufficient quantities to preserve the milk and prevent the development of some of the bacteria without having any deleterious effects on the digestibility of the milk in vitro under artificial conditions. These conclusions can not be accepted as applying to natural digestion in the stomach especially in view of the almost unanimous findings of physiologists against the use of formaldehyde in milk or other food products.

In recent years, von Behring has at various times recommended the use of formalin in the preservation of the milk of cows which had been rendered immune to tuberculosis or which may be suspected of excreting tubercle bacilli with their milk. The idea underlying this recommendation of von Behring is that formalin when used in the proportion of 1 part to 10,000 of milk will destroy the tubercle bacilli which may be present in milk without affecting the immunizing bodies which may also occur in the milk. In this way it was suggested that milk might have a slight immunizing effect toward tuberculosis. No confirmation of this view has been obtained and the matter seems to have little practical importance.

Boric Acid and Borax.

The two boron compounds most frequently used in attempts to preserve milk are boric acid (H_3BO_3) and borax or sodium borate ($Na_2B_4O_7 + H_2O$). The free boric acid is obtained by decomposing borax in aqueous solution in strong HCl. Borax is obtained in enormous quantities in Death Valley and elsewhere.

According to the experiments of Buchholtz it is necessary to use a 6-per cent solution of borax or boric acid in order to prevent the growth of molds in sugar solutions. It has also been found that typhoid bacilli will grow in a 1 per cent solution of boric acid. Kitasato recommends that boric acid should be stricken from the list of disinfectants. Experiments by Koch showed that anthrax bacilli remain alive for 100 days in a 2-per cent solution of boric acid and that even a 5-per cent solution of borax for 10 days showed little effect upon the growth of anthrax bacilli. It is quite apparent that borax has a weak germicidal effect and must, therefore, be used in large quantities in order to destroy pathogenic bacteria which may be found in milk. With regard to the effect of borax upon the spontaneous coagulation of milk, Lange found that in the case of milk which would naturally coagulate in 2½ days, 1 per cent of boric acid prevented coagulation for 7 days and 2 per cent prevented coagulation for an indefinite time. In other experiments the development of lactic-acid

bacteria has been very materially checked in fresh milk by the addition of 0.25 to 0.5 per cent of boric acid. On the other hand Rechter found that even 4 per cent of borax did not prevent the growth of liquefying and putrefactive bacteria but did check the development of lactic-acid bacteria.

If boric acid is added to milk, the latter acquires a liquefying property in the presence of a high percentage of lactic acid and bitterness may be observed in milk treated with borax or boric acid. Most of the borax added to fresh milk may be removed by running the milk through a separator, and boric acid added to cream is largely removed in the buttermilk and washing water. The action of rennet is invariably hindered by the use of borax.

As to the effect of borax upon human beings and experimental animals only the briefest summary of the literature need be made here since it is too extensive to be referred to in detail. In feeding experiments it has been found that 0.2 gm. of boric acid is poisonous to guinea pigs. The nitrogen metabolism of dogs is not always affected by feeding them daily doses of 3 gm. of boric acid. Boric acid has been used in the treatment of epilepsy and certain other diseases and when thus administered in doses of 2 to 3 gm. daily for several months, it almost invariably causes skin eruptions. In fact its use even for short periods may result in a drying of the skin and exanthema or papules in which some of the boric acid is excreted. Kister found that daily doses of 1 gm. of boric acid or less caused diarrhea, nausea, albuminuria, and loss of weight. The irritating effect of boric acid may be quite pronounced when used as a mouth wash. In some individuals the mucous membrane is eroded by the use of a 4-per cent solution of boric acid. In some cases a persistent inflammation of the mucous membrane of the mouth has been brought about by the use of a wash of boric acid. In rabbits, guinea pigs, and other experimental animals the internal use of boric acid has caused diarrhea, weakness, and subnormal temperature. An irritation of the digestive tract, gastric pain, and diarrhea have been reported from the administration of a single dose of 2gm. of boric acid. Cats also appear to be susceptible to borax and may be readily killed by repeated doses of this substance. In the experiments reported by Liebreich, rabbits and dogs appeared to endure the continued administration of borax or boric acid without noticeably harmful results.

The most extensive experiments to determine the effect of boric acid and borax upon man have been carried out by Wiley and his assistants. These expriments, as is generally well known, were made on voluntary subjects who were previously determined to be in normal health. In these experiments it was found that both boric acid and borax taken into the stomach were largely excreted by the kidneys at least to the extent of 80 per cent. In the whole series of experiments a marked tendency was noted to lose in body weight. The preservatives appeared to have no effect upon the number of the blood cor-

puscles but gave a strongly alkaline reaction to the urine and increased its content of albumin. The quantity of phosphoric acid excreted was also larger than is normally the case.

Wiley concludes from his experiments that it is unsafe to use borax or boric acid even in the minutest doses in any food product. This ground seems justifiable for the reason that it is impossible for any individual to determine how much borax he is eating daily, if this preservative is used in a great variety of foods. The individual is, therefore, not in a position to limit the daily dose of borax so long as it is used in the preparation of these foods. The continued use of boric acid to the extent of 4 or 5gm. per day produced a loss of appetite, inability to work and decided illness. In many cases the same results were produced from the use of 3 gm. per day or exceptionally even from 1 gm. "It appears, therefore, that both boric acid and borax when continuously administered in small doses for a long period or when given in large quantities for a short period create disturbances of appetite, of digestion, and of health."

Hydrogen Peroxid.

This antiseptic depends largely for its germicidal and physiological action upon its powerful oxidizing property. As is apparent from its formula (H_2O_2) it may be readily made to yield up some of its oxygen which combines with other substances producing a rapid oxidization. Peroxid of hydrogen is a powerful oxidizer of animal tissues, starch, and sugar. It has been somewhat used in medicine in the treatment of fevers and whooping cough but in this regard its use is declining. As an antiseptic, particularly for suppurating ulcers and sores its finds great favor. When used at the rate of 1:100 it is an energetic disinfectant. At the rate of 1:352 it kills anthrax spores within a few days but at the rate of 1:1,000 its antiseptic power is weak. Peroxid of hydrogen has been used as a mouth and nose wash in cases of scarlet fever, diphtheria, and similar diseases. As ordinarily understood it is usually free from poisonous properties and on account of the fact that it is so easily decomposed there is less objection to the use of hydrogen peroxid in milk than to any other preservative which has been suggested. Commercial peroxid of hydrogen contains 3 per cent of pure H_2O_2 in solution in water. In a pure state H_2O_2 begins to give up some of its oxygen at 60°F. but in water this does not take place below a temperature of 100°F. In milk peroxid of hydrogen is readily decomposed giving up some of its oxygen in oxidizing milk sugar. Under ordinary conditions it is probable that hydrogen peroxid is entirely removed by the pasteurization of milk.

In experiments by Huwart it was found that the pasteurization of milk immediately after the addition of hydrogen peroxid removed about two-thirds of this antiseptic and that pasteurization at the end of 18 hours removed every trace of it. Gonnet, for a period of two

months, drank ½ liter of milk daily containing 8 per cent of hydrogen peroxid and without experiencing the least harmful effects. At the same time it was found that 1 cc. of hydrogen peroxid would preserve 1 liter of milk for 2 days. A number of French investigators have recommended the use of $H_2 O_2$ in milk as entirely unobjectionable provided the solution contains no free acid. In experiments by Chick it appeared that the addition of 0.2 per cent H_2O_2 was sufficient for the complete sterilization of milk and that .1 per cent sufficed to keep the milk sweet for a week or longer. The milk acquired a striking flavor, however, which was noticeable even when the $H_2 O_2$ was used at rate of 1 part to 10,000. Chick, therefore, recommends that $H_2 O_2$ be used in the preservation of samples but not in market milk.

While hydrogen peroxid in a fresh state is a vigorous antiseptic, it decomposes so rapidly under the influence of heat or in the presence of organic compounds that its antiseptic value in a compound like milk is not very great. In milk it does not destroy pathogenic bacteria. It has been found, however, that the number of bacteria in dry milk preparations is reduced by treating the milk with $H_2 O_2$ before desiccation.

The use of hydrogen peroxid in milk has been so thoroughly tested and recommended by Budde that the method has acquired the name Buddeizing and is often referred to under that name. The method as proposed by Budde depends on the action of nascent oxygen on the micro-organisms in milk at a temperature above 40°C. Hydrogen peroxid is added to milk at the rate of 0.9 gm. per liter after which the milk is rapidly heated to 50°C. It is stated that the excess of hydrogen peroxid may be rendered innocuous by the addition of a sterile infusion of common yeast. Renard has reported a number of observations on the rate of decomposition of hydrogen peroxid in milk. It appears that a 2-per cent solution in milk was completely decomposed in from 6 to 8 hours.

While hydrogen peroxid is free from the objections of positive harmfulness which clings to other preservatives it has not always been found to be a satisfactory antiseptic for destroying bacteria in milk and often gives a disagreeable flavor to the milk. Its effectiveness as a milk preservative is, therefore, so slight that no relaxation can be allowed in the observation of the rules for cleanliness and the application of cold. For this reason it appears undesirable to recommend or even permit its use in milk.

Other Preservatives.

Sodium Carbonate.—Sodium carbonate and other alkalis can scarcely be considered as preservatives. They are used merely for the purpose of neutralizing the acidity of milk. The use of such substances can not be too highly condemned for the reason that the only purposes of adding them is to prevent the detection of the abnormal souring of milk which has already taken place.

Benzoic acid is obtained from benzoin by sublimation or is prepared artificially. The most common salt of this acid which has been used as a preservative in milk and other foods is sodium benzoate. This salt is more effective as a germicide than boric acid but is open to the objection of producing undesirable effects in man.

Chromates are rarely if ever used in this country in the preservation of milk but in Europe they have occasionally been found associated with formaldehyde sometimes to the extent of 1 part in 1,000.

Saccharin has a very weak antiseptic action and is of little or no value in destroying bacteria in milk. Moreover in repeated doses of 1/4 gm., it causes harmful physiological results.

Salicylic acid and its salts are quite often used in the treatment of rheumatism and gout. Extensive experiments under the direction of Wiley have shown that the popular belief that salicylic acid is the most injurious of all the preservatives is not well founded. It is harmful but not more so than other preservatives which have been used in milk and other food products. The general effect of salicylic acid and its salts is at first to stimulate the digestive organs to greater efforts and to increase the solubility and absorption of foods. The after effects, however, are depressing, the tissues are broken down more rapidly than they are built up and the metabolic processes are interfered with. The use of salicylic acid and its salts has a tendency to diminish the weight of the body, to produce symptoms of weakness or positive illness, to place an additional burden upon the kidneys, and to act as a depressant upon digestion and the general health. The results obtained by Wiley and his assistants in the study of salicylic acid have been largely confirmed by Leffman and other investigators.

Fluorids.—Fluorids are little used as either milk or butter preservatives in this country. In France and other parts of Europe their use is reported from time to time. The presence of sodium or ammonium fluorids in butter to the extent of 0.04 per cent prevents the action of ptyalin and pepsin and, to some extent, that of diastase. Milk may be kept sweet for 2 or 3 days by the use of 0.2 gm. per liter of sodium fluorid but the harmful effects of fluorids should be sufficient reason for prohibiting their use.

Potassium permanganate has occasionally been used in the preservation of milk samples but is inferior to potassium bichromate for this purpose.

Potassium chromate is now and then added to milk at the rate of 0.2 gm. per liter in order to give it a yellow color. Among the other preservatives which have in rare instances been used in milk, mention may be made of sulphites and copper sulphate. Milk treated with copper sulphate becomes slimy with long standing instead of curdling. The antiseptic action of copper sulphate appears to be very slight.

Proprietary Preservatives.—As already mentioned the proprietary preservatives which have been placed upon the market with various guarantees concerning their harmless properties and efficient action have all been found upon examination to be composed of the well-known chemical substances which have been discussed in the above list of preservatives. It is not necesssary, therefore, to discuss this matter any further.

General Conclusions on the Use of Preservatives in Milk.

The recent decision of officials entrusted with the examination of the effects of preservatives, and of other chemists and sanitarians throughout the world have established beyond question the fact that it is impossible to use chemical preservatives which will prevent the decomposition of food products and destroy pathogenic or other bacteria without exercising an injurious effect upon the digestive and other organs of the body. It seems impossible, therefore, to draw any other conclusion regarding the use of preservatives in milk than that they are unnecessary, undesirable, and positively injurious. They are unnecessary for the reason that milk will keep sweet a sufficient length of time if it is clean and cool. Preservatives in milk are undesirable for the reason that they suggest relaxation in general sanitation about the dairy. There can be little question that their use in the hands of the unscrupulous promotes carelessness and filthiness in the stable and in the handling of the milk. The preservatives which have thus far been used or suggested for use in milk do not possess an antiseptic power sufficient to destroy pathogenic bacteria in the dilution in which they must be used in milk in order not to be poisonous. Since, therefore, pathogenic bacteria can not be safely destroyed in milk by the use of chemical preservatives, these substances constitute an added source of danger in that certain individuals are disposed to rely upon them for destroying disease germs, which they do not, and for the further reason that they are in themselves injurious to health.

CHAPTER XI.

PHYSICAL AND CHEMICAL EXAMINATION OF MILK.

The physical and chemical methods which have been proposed for determining the composition, adulteration, coloring or other artificial treatment of milk are too numerous and some of them are too restricted in their use to make a general discussion of all these methods desirable in the present chapter. A description will be given of the principal methods which find favor in present practice in this country, and a briefer mention will be made of some of the other methods.

Testing Cows for Dairy Purposes.

The farmers who test their own cows and keep a record of their fat and milk yield are in position to appreciate the necessity of testing market milk. Every dairyman should keep a record of the performance of each of his cows. In this way he will know which cows are very profitable and which ones lower the profits from his dairy as a whole. Cows of similar appearance and conformation may differ greatly in their milk yield and fat production. In applying tests to dairies throughout the country it has been found that in almost every dairy there are cows which do not give enough butter fat to pay for their keep, while there are others in the same dairy which produce three or four times as much butter. It pays the dairyman therefore to know what each cow is doing. After having applied the test he can dispose of all cows which yield less than 200 pounds of butter per year.

It is a very easy matter to test cows. Milk scales can be obtained from all dealers in dairy supplies, and it takes but a moment to weigh the milk at each milking. If this be done the total yield of each cow will be known. Even if every milking is not weighed, the milk should be weighed two days of each week. It is not necessary to make a daily test for fat in each cow's milk. In determining whether a cow is good enough to buy or not a fairly correct idea of her fat production can be obtained from two tests. The first should be made about 6-10 weeks after calving, and the second after six or seven months. The dairyman will find it desirable to make a fat test of all cows in his herd every two weeks or at longest every month. Each test should be made upon a composite sample of milk made up of small samples taken each morning and evening for four days in succession. A test from a sample taken at one time is never representative. The fat content of the milk varies too greatly from day to day. A good average sample is obtained by mixing samples from four days' milkings. When a sample is to be taken the cow should be thoroughly milked and the milk well mixed before sampling. Milking a few streams directly

into a sample bottle will never give an average sample, for the fat content increases from the beginning to the end of the milking. The samples must be kept in tightly stoppered bottles and the other direction followed as usually recommended for making the Babcock test and as is described below.

By means of the Babcock tester the farmer may not only determine the relative value of his cows, but he may also test the cream obtained by the gravity or centrifugal methods. A test may also be made of the skim milk and the efficiency of separation thus determined. An examination of the buttermilk will show whether churning is done under proper conditions.

Examination of Market Milk.

Naturally the milk inspector in the examination of market milk will limit his operations to the points specified in the law from which he derives his authority. Municipal milk inspection regulations are too often inadequate to protect the health of the milk consumer. The mere removal of a part of the cream from milk does not render the milk harmful although it is a palpable fraud. On the other hand the presence of peptonizing or pathogenic bacteria is a menace to health. Removal of cream from market milk is a deliberate perpetration of a fraud, the use of preservatives is an attempt to cover up the evidence of careless or insanitary handling of milk, but the presence of pathogenic bacteria is due to an unconscious, or in some cases an almost criminal carelessness.

In some towns the inspector merely determines whether the fat percentage is up to the standard. In others he tests for fat and total solids. In still others attention is given also to specific gravity, temperature. dirt, bacteria etc. A complete examination of market milk should take cognizance of specific gravity, temperature at time of delivery, fat, total solids, pasteurization, contamination with dirt and bacteria, acidity, flavor, odor, color, and addition of preservatives, adulterants and coloring matters. The methods of taking samples of milk for examination, of determining specific gravity, fat, total solids, proteids, sugar, ash and acidity, and of detecting preservatives, adulterations and coloring matters are discussed in the following sections of this chapter. The methods are those which have been adopted by the Association of Official Agricultural Chemists, or are recommended by Richmond, Van Slyke, Farrington and Woll, Webster, Hills and other investigators.

Taking, Preserving and Caring for Samples.

It is of the greatest importance that each sample of milk taken for analysis or examination should represent the true average composition of the milk to be tested. If the constituents of the milk are not thoroughly mixed in their normal proportions before the sample is taken, the results obtained from the test of the sample will be of no

value, but rather misleading. Several precautions are therefore strictly to be observed in sampling milk. If the milk is perfectly fresh and no appreciable rising or clumping of the cream has taken place a thorough mixing will insure an average composition to the sample. At creameries the milk is sufficiently mixed by pouring into the weigh can. Otherwise it may be poured from one can to another, or mixed by stirring. Too violent stirring should be avoided since a partial churning may result, making it more difficult to get a representative sample. If a distinct layer of cream has risen to the surface the mixing must be continued longer but must be gentle. Milk containing dried or hardened cream is to be heated for 5-10 minutes to a temperature of 105-110° F., or until the clumps of cream are melted. It is then stirred and sampled.

Milk transported in partly filled cans and violently agitated may be partly churned when examined by the inspector. In such cases also it should be warmed till the cream melts after which it is mixed by pouring or gentle stirring and sampled. In all cases samples may be taken with a half-ounce milk dipper or with a sampling tube. Ether may be used in the place of heat to dissolve clumps of cream. If 5 per cent of ether be shaken with the milk till the cream is dissolved, and the mixture again shaken vigorously to redistribute the cream a representative sample may be obtained. After such treatment the fat reading should be increased by 5 per cent as a correction for the added ether.

In sampling coagulated milk Van Slyke recommends that 5-10 per cent of strong soda or potash lye or ammonia water be added to dissolve the casein. The milk is shaken till it becomes liquid after which it is immediately sampled. In testing milk treated in this manner the sulphuric acid must be poured in slowly since a high degree of heat is developed.

In freezing, the constituents of milk become very unevenly distributed. The cream is largely caught in the ice at the surface. Other frozen portions are poor in solids, while the liquid portion is rich in solids. Frozen milk must be melted by heat and thoroughly mixed before sampling.

A composite sample is a mixed sample taken day after day from the same source. Thus a composite sample from a single cow contains portions of the morning and evening milkings of two or more days in succession. Composite samples in creamery work are made up in the same manner from the milk delivered day after day by the same patron. The daily samples are allowed to accumulate in a jar or bottle for one or two weeks. The jar or bottle should be tightly stoppered so as to prevent all evaporation. In order to keep a composite sample in condition for testing it is necessary to use some kind of preservative. For this purpose bichromate of potash, formalin and corrosive sublimate are most used.

A choice of preservatives will depend somewhat on experience.

Farrington and Woll prefer bichromate of potash on the grounds of harmlessness, cheapness and efficiency. One half gram will preserve a pint of milk for one or two weeks. At first the milk is colored red but later the color becomes lighter. As shown by Van Slyke hot weather may make it necessary to use more bichromate of potash, and lactic acid interferes somewhat with its efficiency. It is always best to keep composite samples in a dark, cool place.

One cc. of formalin will keep a pint of milk in good condition for the required time. The excessive use of either formalin or corrosive sublimate will harden the casein so that it is less readily dissolved by the sulphuric acid in testing.

Corrosive sublimate is a powerful antiseptic but is very poisonous and the milk does not indicate its presence. Tablets of corrosive sublimate containing a coloring matter to denaturize the milk are put up specially for this purpose. Penny has tested a large number of other preservatives for milk samples, including hydrogen peroxide, bromine, iodine, caustic potash, ammonia, potassium carbonate, ammonium carbonate, magnesia, sodium chloride, barium chloride, ammonium chloride, calcium chloride, stannous chloride, potassium iodide, nitrate of sodium, potassium, magnesium, ammonium, strantium, silver and lead, potassium sulphate, potash alum, sulphate of magnesium and zinc, sodium thiosulphate, potassium chlorate, ammonium sulphide, potassium sulphocyanate, potassium ferrocyanide, potassium permanganate, chromic acid, boric acid, formate of ammonium and calcium, lead acetate, ammonium oxalate, alcohol, ether, glycerine, benzene, salicylic, carbolic and tannic acids, oil of peppermint, oil of cloves, camphor, quinine, tobacco, etc. There seems, however, to be little reason to use any preservative other than bichromate of potash, formalin or corrosive sublimate. Penny has experimented with the method of submergence in preserving milk samples. This consists in using a solvent heavier than milk to dissolve the fat and carry it to the bottom of the sample where it is preserved in a better physical condition than when it rises to the surface. The chief solvents used for this purpose were ethyl bromide, carbon bisulphide and chloroform. These solvents are too expensive for practical use and must be driven out of the milk before the test is made. This may be done by adding acetic acid and boiling.

Whether formalin, corrosive sublimate, or bichromate of potash is chosen the entire amount should be added to the first lot of milk placed in the sample jar. The preservative must be mixed with the milk by slowly rolling the jar. Every time a new lot of milk is added the whole should be thoroughly mixed. In the intervals the jars may be gently shaken to prevent the formation of a tough layer of cream on the surface.

Sampling cream.—In sampling cream the same precautions are to be observed as with milk. The fat in cream has a tendency to rise to the surface as in milk. It is more necessary to melt cream than is

usually the case with milk in order to get a correct sample. Hills recommends that the composite sample of cream be heated to 105-110 F. before the amount to be tested is removed. Hills also devised a cream sampling sieve through which the cream is passed in order to break up the clumps.

Determination of Specific Gravity.

The determination of the specific gravity of milk is of importance because when once known together with the fat percentage the amount of solids not fat may be calculated by formulas worked out by Babcock and others. If a vat which will contain exactly 1000 pounds of water is filled with milk the latter will weigh about 1032 pounds. The average specific gravity of milk is therefore said to be 1.032. The casein, albumin and sugar of milk are heavier than water while the fat is lighter. If fat is removed from milk its specific gravity is raised while by the addition of water it is lowered. It is possible therefore to remove some of the fat and then add enough water to make the specific gravity that of normal milk. It is thus impossible always to detect defective milk by its specific gravity. The determination of specific gravity, however, is of value in detecting highly abnormal milks.

The instrument most frequently used for this purpose is the lactometer of which there are two in common use in this country, the Quevenne and that of the New York Board of Health. The lactometer is a hygrometer specially adapted for use in testing milk. The scale of the Quevenne lactometer is divided into 25 equal spaces, ranging from 15 to 40, and corresponding to the hygrometer readings 1.015 to 1.040. Milk to be tested is supposed to be at a temperature of 60° F. A correction of .1 is to be added to each degree above 60° F. and the same subtracted for each degree below 60° F. The lactometer is placed so that it floats freely in the milk. The point on the scale at the surface of the milk is then noted and also the temperature of the milk. Corrections are then made for temperatures above or below 60° F. The milk should preferably be near 60° F.

In the New York Board of Health lactometer the zero point is at the top of the scale which is divided into 120 equal spaces. The zero point indicates a specific gravity of 1.029, the lowest known for normal milk. One degree on the New York Board of Health lactometer equals .29 of a degree on the Quevenne. A New York Board of Health reading is converted into a Quevenne reading by multiplying by .29. A correction of .3 is made for temperatures above or below 60° F. Milk should be one or two hours old before testing and the lactometer should be scrupulously clean.

Babcock's formulas for determining solids. If L be the Quevenne reading and f the fat percentage, then the solids not fat $= \frac{1}{4}L + .2f$, and the total solids $= \frac{1}{4}L + 1.2f$. These formulas give results which closely agree with those obtained with Richmond's slide rule, which is accompanied with directions for its use.

There are several other lactometers on the market but they are not so commonly used in this country. The lactometers of Soxhlet and Vieth both have a scale which reads from 25 to 35. Galaine's lactometer is self correcting for the various temperatures of the milk. Richmond considers the thermolactometer and Soxhlet's and Vieth's as the best for testing milk.

Pycnometer.—By the use of a pycnometer more accurate results are obtained than with a lactometer. As performed by Farrington and Woll the test is made as follows. A specific gravity bottle holding 100 gm. of water is carefully cleaned, weighed on a chemical balance and filled with recently boiled water at a temperature slightly below 60°F. The opening of the side tube is then wiped off and closed. The outside of the bottle is wiped dry and the bottle weighed. The same process is then gone through with milk. The weight of the empty bottle subtracted from that of the bottle filled with water and with milk will give the weight of the water and milk respectively. The specific gravity of the milk is found by dividing the weight of the milk by that of the water. Fraudulent skimming is clearly indicated if the specific gravity is 1.040 or higher.

Determination of Fat.

The fat in milk may be estimated by the volumetric, gravity, densimetric, areometric and other methods. The volumetric method is sufficiently exact for the control of market milk, and of the methods belonging to this class that of Babcock is almost universally used in this country.

The Babcock test.—The great advantages of the Babcock test are its simplicity and ease of operation. The method depends simply upon centrifugal force and the action of sulphuric acid on milk serum. Sulphuric acid dissolves the milk proteids, reduces the viscosity of the milk and increases the specific gravity of the serum. The heat developed in the mixture of milk and acid causes the fat globules to coalesce. The centrifugal force brings about a rapid separation of the fat and serum. Babcock testers may be operated by hand or by steam turbine action. The apparatus consists of test bottles, pipette for measuring milk, acid measure and centrifugal machine. In making a test exactly 17.6 cc. of milk is drawn into the pipette, it being estimated that .1 cc. will adhere to the pipette in emptying. This milk is poured into the test bottle, the latter being held on the slant so that the milk runs down one side. Exactly 17.5 cc. of sulphuric acid of a specific gravity of 1.82 or 1.83 at 60°F. is measured out in the acid measure, and poured down the slanting neck of the test bottle, being mixed with the milk by a rotary motion. The mixture is allowed to stand about five minutes and mixed again. The temperature of both the milk and acid should be between 60° and 70°F. The bottles are then placed in the tester and whirled for 4 or 5 minutes at a speed of 600 to 1200 revolutions per minute according

to the diameter of the wheel. As stated by Farrington and Woll the necessary number of revolutions for a ten inch wheel is 1074 per minute, and for a 24 inch wheel 693 per minute. After the first whirling add fairly hot water to bring the mixture up to the neck of the bottles and whirl for one minute. Again add hot water to bring the mixture up to the 8 or 9 per cent mark and whirl one minute. The per cent of fat may then be read while the temperature of the milk is about 130° F. The lower surface of the column of fat is straight and offers no difficulty in reading. The upper reading should be taken at the point where the fat comes in contact with the neck of the bottle. Black specks in the column of fat may be due to too much acid, too strong acid or too high a temperature. White specks of undissolved casein in the fat may be due to too weak acid, too little acid or too low temperature. Foam on the fat column is usually due to the use of hard water. Only soft water should be used. All apparatus in this test should be calibrated before using.

Gerbers acidobutyrometer.—This method is essentially a modification of that of Leffman-Beam. Amyl alcohol is used in addition to sulphuric acid to hasten the separation of the fat. The method gives fairly good results.

In a number of patented tests such as the sin-acid and Gerber's sal-test no acid is used. In the De Laval butyrometer only 2 cc. of milk is used and the rate of revolution is 5000 to 6000 per minute. In Fjord's centrifugal cream tester no chemicals are used, the milk being whirled for 20 minutes at a rate of 2000 revolutions per minute at a temperature of 131° F. The chemicals used in the Leffman-Beam method are sulphuric acid, and amyl alcohol mixed with hydrochloric acid. The advantage claimed for this method is that the necessary time of whirling is reduced. The Russian milk test is the regular Babcock test so modified that the bottles can be filled with hot water while being whirled. Bartlett modified the Babcock test by using 20 cc. instead of 17.5 cc. of acid and filling the bottles to the scale with hot water. The milk is whirled only once. The lactoscope is essentially a Fjord centrifugal cream test modified so as to be attached to a separator. It was devised by Berg and is considered fairly accurate. Among the other tests which have been published mention may be made of that of Willard, Parson, Cochran, Patrick, Liebermann, Schmid, Röse-Gottlieb, Thoerner, Demichel Lescoeur, Smith, Weiss and others. The milk inspector in this country, however, need apply no other volumetric test for fat than that of Babcock.

The areometer test of Soxhlet.—In this test 200 cc. of milk is run into the test bottle after which 10 cc. of potash solution is added (with a specific gravity of 1.26 or 1.27, and made by dissolving 400 gm. of caustic potash in one liter of water), and also 60 cc of ether. The bottle is first violently shaken and later gently shaken every half minute until a clear layer of dissolved fat rises to the surface. Enough

of the etherial solution is then blown up into the jacketed tube to float the areometer and the reading is made.

The Adams method.—This is perhaps the best known of the European gravimetric methods for estimating the fat of milk. The original method consisted in pipetting 5 cc. of milk into a beaker after which a roll of blotting paper was introduced and make to absorb the milk as completely as possible. The weight of the milk thus absorbed is determined, and the coil of blotting paper is dried to a constant weight in an oven at a temperature of 100°C. In this way the total solids as well as the fat may be determined. The dry coil of blotting paper is placed in a Soxhlet extractor. The total extract after the ether is evaporated is considered fat. Various modifications of this method have been proposed. A fat-free paper was devised by Schleicher and Schüll to secure greater accuracy in estimating the milk fat. In the place of blotting paper other substances have been used such as pumice stone, kaoline, plaster of Paris, kieselguhr, asbestos etc.

Babcock asbestos method.—Official.—"Extract the residue from the determination of water by the Babcock asbestos method with anhydrous ether until all the fat is removed, evaporate the ether, dry the fat at the temperature of boiling water, and weigh. The fat may also be determined by difference, drying the extracted cylinders at the temperature of boiling water."

Paper coil method.—Official.—"Make coils of thick paper, cut into strips 6.25 by 62.5 cm., and thoroughly extract with ether and alcohol, or correct the weight of the extract by a constant obtained for the paper. From a weighing bottle or weighing pipette transfer about 5 gm. of milk to the coil, care being taken to keep the end of the coil held in the fingers dry. Dry the coil,dry end down, on a piece of glass at the temperature of boiling water for one hour, or, better, in hydrogen at the temperature of boiling water; transfer to an extraction apparatus, and extract with absolute ether or petroleum ether boiling at about 45°C.; dry the extracted fat and weigh." Bell, Storch, Soxhlet, Werner-Schmid, Ritthausen and others have devised other gravity methods for estimating fat in milk, but the gravity methods already described are all that the milk inspector will need in practice.

The heat evolved by hydrolysis of fat by sulphuric acid was used by Maumené as a test for milk fat. The method has been modified by Thompson, Ballantyne and Richmond, but is irregular in results and is not recommended.

Densimetric method.—Richmond has found that if 200 cc. of milk be poured on a pleated filter all but .12 per cent of the milk serum runs through in 15 minutes. It appears that "if the specific gravity of the filtered milk less 1 be divided by .004, and the differ-

ence between the specific gravities of the milk before and after filtration be divided by .0008, the figures so obtained represent very fairly the solids not fat and fat respectively."

Refractometer.—In the examination of butter fat the refractive index may be determined by means of a refractometer such as that of Wollny. The results obtained are more accurate than by the Gerber butyrometric method, but owing to the great care required in the manipulation of the method, the many different steps, the expense of the reagents, etc., the method is not recommended.

Total Solids.

The methods recommended by the Association of Official Agricultural Chemists are as follows:

Method I.—Heat from 1 to 3 grams of milk until it ceases to lose weight, at the temperature of boiling water in a tared flat dish of not less than 5 cc. in diameter. If desired from 15 to 20 grams of pure dry sand may be previously placed in the dish. Cool in a dessicator and weigh rapidly to avoid absorption of hydroscopic moisture.

Babcock asbestos method.—Provide a hollow cylinder of perforated sheet metal, 60 mm. long and 20 mm. in diameter, closed 5 mm. from one end by a disk of the same material. The perforations should be about .7 mm. in diameter and about .7 mm. apart. Fill loosely with from 1.5 to 2.5 grams of freshly ignited woolly asbestos, free from fine and brittle material, cool in a desiccator and weigh. Introduce a weighed quantity of milk (between 3 and 5 grams) and dry at the temperature of boiling water to constant weight.

The total solids of milk may also be determined by Babcock's formulas mentioned above, by the use of Richmond's slide rule or by Adams' gravimetric method.

Total Proteids.

The official method for the determination of total proteids is as follows. Place about 5 grams of milk in a Kjeldahl digestion flask and proceed without evaporation for the determination of nitrogen. Multiply the percentage of nitrogen by 6.25 to obtain nitrogen compounds.

Casein.

"The determination should be made when the milk is fresh or nearly so. When it is not practicable to make this determination within 24 hours, add 1 part of formaldehyde to 2500 parts of milk, and keep in a cool place. Place about 10 grams of milk in a beaker with about 90 cc. of water at 40° to 42° C., and add at once 1.5 cc. of a 10 per cent acetic acid solution. Stir with a glass rod and let stand from 3 to 5 minutes longer. Then decant on filter, wash two or three times with cold water by decantation, and transfer precipitate completely to filter. Wash once or twice on filter. The filtrate should

be clear or nearly so. If it be not clear when it first runs through, it can generally be made so by two or three repeated filtrations, after which the washing of the filtrate can be completed. Determine nitrogen in the washed precipitate and filter paper by the Kjeldahl or Gunning method. To calculate the equivalent amount of casein from the nitrogen multiply by 6.25.

In working with milk which has been kept with preservatives, the acetic acid should be added in small proportions, a few drops at a time, with stirring, and the addition continued until the liquid above the precipitate becomes clear or nearly so."

The following simple rule for finding the per cent of casein has been worked out by Van Slyke. "To find the per cent of casein in milk when the per cent of fat is known, subtract 3 from the per cent of fat in milk, multiply the result by .4 and add this result to 2.1."

Albumin.

The method for determining albumin in milk recommended by the Association of Agricultural Chemists is as follows: "Exactly neutralize with caustic alkali the filtrate obtained in the determination of casein, add .3 cc. of a 10 per cent solution of acetic acid and heat the liquid to the temperature of boiling water until the albumin is completely precipitated, collect the precipitate on a filter, wash, and determine the nitrogen therein. Nitrogen multiplied by 6.25 equals albumin."

Milk Sugar.

"Acid mercuric nitrate.—Dissolve mercury in double its weight of nitric acid, specific gravity 1.42, and dilute with an equal volume of water. One cc. of this reagent is sufficient for the quantities of milk mentioned below. Larger quantities may be used without affecting the results of polarization.

Mercuric iodide with acetic acid.—Mix 33.2 gm. of potassium iodide, 13.5 gm. of mercuric chloride, 20 cc. of glacial acetic acid and 640 cc. of water.

The milk should be at a constant temperature and its specific gravity determined with a delicate hydrometer. When greater accuracy is required, a pycnometer is used.

The quantities of milk measured for polarization vary with the specific gravity of the milk as well as with the polariscope used. The quantity to be used in any case will be found in the following table:

Specific gravity	Volume of Milk to be used	
	For polariscopes of which the sucrose normal weight is 16.19 gm.	For polariscopes of which the sucrose normal weight is 26.048 gm.
1.024	60.0 cc	64.4 cc
1.026	59.9	64.3
1.028	59.8	64.15
1.030	59.7	64.0
1.032	59.6	63.9
1.034	59.5	63.8
1.035	59.35	63.7

Place the quantity of milk indicated in the table in a flask graduated at 102.4 cc. for a Laurent or 102.6 cc. for a Ventzke polariscope. Add 1 cc. of mercuric nitrate solution or 30 cc. of mercuric iodide solution (an excess of these reagents does no harm), fill to the mark, agitate, filter through a dry filter, and polarize. It is not necessary to heat before polarizing. In case a 200 mm. tube is used, divide the polariscope reading by 3 when the sucrose normal weight for the instrument is 16.19 gm., or by 2 when the normal weight for the instrument is 26.048. When a 400 mm. tube is used these divisors become 6 and 4 respectively. For calculation of the above table the specific rotary power of lactose is taken as 52.53°, and the corresponding number for sucrose as 66.5°. The lactose normal weight to read 100° on the sugar scale for Laurent instruments is 20.496, and for the Ventzke instruments, 32.975. In case metric flasks are used the weights here mentioned must be reduced accordingly."

Method by use of Fehling's solution.—This method depends upon the oxidation of sugar by an alkaline copper solution, and the reduction of copper to cuprous oxide. It is a gravimetric method and may be found by consulting the official methods of analysis of the Association of Agricultural Chemists. The method has been variously modified by different investigators.

There are still other tests for lactose but the milk inspector will scarcely have occasion to use more than those given above. As a matter of fact milk sugar is commonly determined by difference, subtracting the sum of the proteids, fat and ash from the total solids.

Ash.

The official method is as follows: "Weigh about 20 gm. of milk in a weighed dish, add 6 cc. of nitric acid, evaporate to dryness, and burn at a low red heat until the ash is free from carbon." The method given by Farrington and Woll is stated as follows: "About 20 cc. of milk are measured into a flat bottom porcelain dish and weighed; about .5 cc. of 30 per cent acetic acid is added, and the milk first dried on water bath, and then ignited in a muffle oven at a low red heat."

Other Constituents.

Lecithin is perhaps best estimated by the determination of phosphoglyceric acid. One hundred cc. of milk is added to a mixture of 100 cc. of alcohol, 100 cc. of water, and 10 drops of acetic acid. The coagulum is separated by filtration and extracted with alcohol. The extract is evaporated to dryness and the residue taken up with ether-alcohol. After evaporation the residue is saponified with potassium or barium hydroxide and the soap decomposed with nitric acid. The filtrate from this is evaporated to dryness and the residue treated with concentrated nitric acid and potassium permanganate. The phosphate is then determined as magnesium pyrophosphate, which multiplied by the factor 1.5495, gives the amount of phosphoglyceric acid in the original sample. Foreign fats in butter fat may be recognized by determining the iodine number, Reichert-Meissl number, or by making the Polenske test.

Acidity.

There are three tests in common use for determining the acidity of milk and cream, Manns, Farrington's and Van Norman's.

Mann's acid test.—Van Slyke's description of this test is followed. Exactly 50 cc. of milk or cream is pipetted into a beaker. The pipette is then filled with distilled water and added to the sample. Five or ten drops of an alcoholic solution of phenolphthalein is added, and the burette belonging to the apparatus is filled to the zero mark with the standard alkaline solution, and a portion of it is allowed to run into the beaker. A pink color appears but disappears after stirring. This process is repeated, gradually diminishing the amount of alkali added each time until the pink color does not disappear after stirring 10 or 15 seconds. The burette is then examined to determine how much of the alkali was used. The per cent of acid may be calculated by the following formula:—per cent of acid = no. cc. of alkali $\times$ .018, where the sample contained 50 cc. of milk.

Farrington's alkaline tablet test.—Farrington, Stokes, Eichler and others have prepared alkaline tablets to take the place of the standard alkaline solution of Mann's test. The neutralizer and indicator are combined in the tablets. Farrington's test may be used for sour cream, sour milk, or buttermilk. The method when a 20 cc. pipette is used is thus described by Farrington and Woll. "When a 20 cc. pipette is used for measuring the sample to be tested, the tablet solution is prepared by dissolving one tablet for every 17 cc. of water; for 5 tablets 85 cc. of water are therefore taken. When made in this way, each cc. of solution represents .01 per cent of acid in the sample tested, 20 cc. of cream being taken; the number of cc. required to produce a pink color in the sample tested as read off directly from the graduations of the cylinder used for making the tablet solution gives the per cent of acid in the sample, 10 cc. being equal to .10 per cent acid,

32 cc. to .32 per cent etc." Spillman has published a slight modification of this method.

Van Norman alkali test for acidity.—The original description of this test is as follows:

"With a Babcock pipette measured into a white cup, or even a common composite sample jar, 17.6 cc. of the cream to be tested, which has been well stirred; rinse the pipette out with clean water, putting the rinse water into the cream sample and add four or five drops of Phenolphthalein indicator. Having filled the cylinder to the top or 100 cc. mark with the 50th normal alkali solution, begin pouring slowly into the cream sample, mixing with a rotary motion of the hand or stirring with a glass rod until there is a pink color noticeable, which does not disappear immediately by continued stirring. Note the number of cc. of the alkali solution required to bring about this result. This will indicate the number of 100th per cent of acidity, since 1 cc. of the alkali will neutralize .01 per cent of acid when 17.6 cc. of milk or cream is used."

Detection of Preservatives and Colors.

Boric acid and borates.—"Render decidedly alkaline with lime water about 25 gm. of the sample and evaporate to dryness on a water bath. Ignite the residue to destroy organic matter. Digest with about 15 cc. of water, add hydrochloric acid, drop by drop, until all is dissolved, and add 1 cc. in excess. Moisten a piece of delicate turmeric paper with the solution, if borax or boric acid is present, the paper on drying will acquire a peculiar red color, which is changed by ammonium hydroxide to a dark blue-green, but is restored by acid."

A simple modification of this method was proposed by the N. J. Dairy Commissioner as stated by Farrington and Woll. "Place in a porcelain dish one drop of milk with two drops of strong hydrochloric acid and two drops of saturated turmeric tincture, dry this on the water bath, cool and add a drop of ammonia by means of a glass rod. A slaty blue color, changing to green, is produced if borax is present."

Formaldehyde.— Hehner's method.—"To the milk to be tested add strong commercial sulphuric acid without mixing, and at the junction of the two liquids a violet or blue color will appear if the milk contains one or more parts of formaldehyde per 10,000. This color is supposed to be given only when there is a trace of ferric chlorid or other oxidizing agent present."

Leach's method.—"Add about 5 cc. of the distillate obtained as described below to an equal volume of pure milk in a porcelain casserole and about 10 cc. of concentrated hydrochloric acid, containing 1 cc. of 10 per cent ferric chlorid solution, to each 500 cc. of acid. Heat to 80° or 90° C. directly over the gas flame, giving the casserole a rotary motion to break up the curd. A violet coloration indicates formaldehyde."

Official method of preparing sample.—"If the material be solid or semisolid macerate 200 to 300 gm. in a mortar with about 100 cc. of

water until a sufficient degree of fluidity is obtained. Transfer to a short-necked distilling flask of copper or glass of from 500 to 800 cc. capacity and make distinctly acid with phosphoric acid. Connect the flask with a glass condenser and distill from 40 to 50 cc.'

Benzoic acid.—"Add 5 cc. of dilute hydrochloric acid to 50 cc. of the milk in a flask and shake to curdle. Then add 150 cc. of ether, cork the flask and shake well. Break up the emulsion which forms by aid of a centrifuge, or if the latter is not available extract the curdled milk by gently shaking with successive portions of ether, avoiding the formation of an emulsion. Transfer the ether extract to a separatory funnel and separate the benzoic acid from the fat by shaking out with dilute ammonium hydroxide, which takes out the former as ammonium benzoate. Evaporate the ammoniacal solution in a dish over the water bath till all free ammonia has disappeared, but before dryness is reached add a few drops of ferric chlorid reagent. The characteristic flesh-colored precipitate indicates benzoic acid. Care should be taken not to add ferric chlorid until all the ammonia has been driven off, otherwise a precipitate of ferric hydrate is formed."

Salicylic acid.—Proceed exactly as directed for benzoic acid. On applying the ferric chlorid to the solution after evaporation of the ammonia the well known violet color indicates salicylic acid.

Sodium carbonate.—Van Slyke gives the following test. "To 10 cc. of milk add 10 cc. of alcohol and a few drops of a 1 per cent solution of rosolic acid. Carbonates are present if a rose or red color appears, while pure milk shows a brownish yellow color." Another test is given by Farrington and Woll. "100 cc. of milk to which a few drops of alcohol are added, are evaporated and carefully incinerated; the proportion of carbonic acid in the ash as compared with that of milk of known purity, is determined. If an apparatus for the determination of carbonic acid is available, like the Scheibler apparatus, the per cent of carbonic acid per gm. of ash (and quart of milk) can be easily determined. Normal milk ash contains only a small amount of carbonic acid (less than 2 per cent), presumably formed from the citric acid of the milk in the process of incineration."

Fluorids.—Richmond's method for the detection of fluorids is as follows: "At least 25 cc. of milk should be taken, and the ash treated in a platinum basin with a little strong sulphuric acid. Over the top of the basin a watch glass coated with paraffin wax, through which a few lines is scratched, is placed, and a piece of ice or some cold water is put into the concave depression. The basin is then gently warmed and the watch glass exposed to the action of the fumes for 10 minutes. In the presence of fluorids it is seen that the glass has been etched, after the removal of the wax. If a drop of water is placed on the paraffin away from the lines scratched through it, a white film of silica will be formed on its surface, if fluosilicates be present. If

fluoborates be present, this drop of water will give a boric acid reaction; in the presence of fluoborates both a fluorid and boric acid reaction are given by the ash of the milk."

Other methods.—Many other methods have been proposed for the detection of preservatives in milk, especially formaldehyde. According to a method used by Leys a colorless solution of phloroglucin (1 gm. in 1 liter), and potash solution (one third ordinary strength) are used. A red color is produced if formaldehyde is present when 25 cc. of milk, 10 cc. of the phloroglucin solution, and 5 to 10 cc. of the potash are shaken in a test tube, the color disappearing after a few minutes. Riegler found that if phenylhydrazin and a 10 per cent solution of soda be added to a small portion of diluted milk, a rose color will result in the presence of even 2 drops of formaldehyde per 100 cc. of milk. Leonard states that if milk treated with formaldehyde be heated with an excess of hydrochloric acid containing a trace of bromine or ferric chlorid a violet color will result. Usually in making the Babcock test with milk treated with formaldehyde a distinct violet color appears at the contact of the acid and milk.

Detection of foreign color.—Leach's method.—"Warm about 150 cc. of milk in a casserole over a flame and add about 5 cc. of acetic acid, after which slowly continue the heating nearly to the boiling point while stirring. Gather the curd, when possible, into one mass by the stirring rod, and pour off the whey. If the curd breaks up into small flecks separate from the whey by straining through a sieve or colander. Press the curd free from adhering liquid, transfer to a small flask, and macerate for several hours (preferably over night) in about 50 cc. of ether, the flask being tightly corked and shaken at intervals.

Annatto.—Decant the ether extract as obtained above into an evaporating dish, place on the water bath, and evaporate the ether. Make the fatty residue alkaline with sodium hydroxid, and pour upon a very small wet filter while still warm. After the solution has passed through, wash the fat from the filter with a stream of water and dry the paper. If after drying the paper is colored orange, the presence of annatto is indicated. Confirm by applying a drop of stannous chlorid solution, which, in presence of annatto, produces a characteristic pink on the orange-colored paper.

Anilin orange.—The curd of an uncolored milk is perfectly white after complete extraction with ether, as is also that of milk colored with annatto.

If the extracted fat-free curd is distinctly dyed an orange or yellowish color, anilin orange is indicated. To confirm the presence of this color treat a clump of fat-free curd in a test tube with a little strong hydrochloric acid. If the curd immediately turns pink, the presence of anilin orange is assured.

Caramel.—"If the fat-free curd is colored a dull brown, caramel is to be suspected. Shake a lump of the curd with strong hydrochloric acid in a test tube and heat gently. In the presence of caramel the acid solution will gradually turn a deep blue, as will also the white fat-free curd of uncolored milk, while the curd itself does not change color. It is only when this blue coloration of the acid solution occurs in connection with a brown-colored curd, which itself does not change color, that caramel is to be suspected, as distinguished from the pink coloration produced at once under similar conditions by alilin orange."

Vandriken has found that if 2 cc. of filtered butter and a like amount of ether be treated with 6 to 10 drops of amyl nitrite, no color change takes place if a coloring matter had been added to the butter, while uncolored butter becomes discolored.

Detection of Heated Milk, Dirt, Adulterants etc.

Heated milk.—Leffman found that when a solution of diamidobenzin is added to unboiled milk, with a few drops of hydrogen peroxid, a deep blue color appears. This reaction does not take place if the milk has been heated to 180° F. Bernstein recommends the following test for pasteurized milk. To 50 cc. of the milk 4.5 cc of a normal solution of acetic acid is added, slightly shaken till the milk has coagulated, filtered, and the clear filtrate heated. If the original milk has not been pasteurized a heavy precipitate of albumin will form. The higher the milk has been heated up to 90° C. the smaller will be the precipitate. Above that no precipitate will occur. Such reagents as alcoholic tincture of guaiac resin, guaiacol, hydrochinon, pyrocatechin etc. will give a coloration in raw milk, probably due to an oxidizing ferment in raw milk.

Storch's test for pasteurized milk.—Storch found that milk retains its power of reducing peroxid up to 79° C. A hydrogen peroxid solution is made by diluting the commercial article with 5 times its volume of water and adding 1 cc. of concentrated sulphuric acid per liter. A teaspoonful of milk is shaken in a test tube with a drop of the peroxid solution and 2 drops of paraphenylendiamin solution. If the milk colors immediately indigo blue it has not been heated. If the milk becomes grayish blue immediately or in half a minute, the indication is that it has been heated to 79° or 80° C. If it retains its original white color or is colored slightly violet red, it has been heated to more than 80° C.

Added water.—The Zeiss immersion refractometer test is made as follows: "To 100 cc. of milk at a temperature of about 20° C. add 2 cc. of 25 per cent acetic acid (sp. gr. 1.035) in a beaker, and heat the beaker, covered with a watch glass, in a water bath for 20 minutes at a temperature of 70° C. Place the beaker in ice water for 10 minutes and separate the curd from the serum by filtering through

a 12.5 cm. folded filter. Transfer about 35 cc. of the serum to one of the beakers that accompanies the control temperature bath used in connection with the Zeiss immersion refractometer, and take the refractometer reading at exactly 20° C., using a thermometer graduated to tenths of a degree. A reading below 39 indicates added water; between 39 and 40 the sample is suspicious." Leach and Lythgoe obtained no refractometer reading with pure milk below 39.

Wisconsin curd test.—Cheese makers are frequently annoyed with gassy curds and it became important to devise a test by which such milk could be detected. A good test for this purpose was devised in the Wisconsin dairy school.

To make the test a fruit jar is filled half full of milk and set in a tub about half full of water sufficiently warm to raise the temperature of the milk to 98° F. When this temperature is reached 10 drops of rennet extract is added to the milk and the jar left undisturbed until the milk is curdled, when the curd is broken into small pieces by stirring with a case knife. The whey is poured off as soon as the curd settles, and this process is repeated at frequent intervals until the curd mats into a solid mass. The temperature of the surrounding water should be maintained from 6 to 8 hours, to favor the rapid development of the organisms in the curd.

"If the milk contains no deleterious bacteria, the curd when cut will present a firm, even texture. If gas-producing bacteria are present the texture of the curd will be more spongy, the cut surface showing a number of holes varying in size, depending upon the prevalence and pas-producing ability of the undesirable bacteria. . . . The conditions under which the curd test is conducted accelerate the fermentative action, so that a milk that might show no symptoms of gas formation until the cheese was on the shelf would be detected when subjected to the curd test. Milks that are sufficiently contaminated to produce floating curds will show a very spongy texture in the test in a few hours. No hard and fast rules can be given for the interpretation of the results of the curd test, but an ordinary operator will very quickly learn to discriminate between milks that should and should not be accepted. . . . It is also possible that taints may be produced by bacterial decomposition in cases where no gas is formed. This is particularly true with that class of organisms that act upon the albumen and casein instead of the milk sugar. Those bacteria that find their way into the milk through the introduction of filth and dust are particularly prone to produce this change, and this type of fermentation is very often found during the summer months. In the curd tests such milks are not condemned upon the texture of the curd, but upon the odor, which is more or less pronounced when the bottle is opened."

Gerber's fermentation test.—This test as described by Van Slyke may be made as follows: "This test consists in heating milk in tubes 6 hours at 104° to 106° F. and then observing the odor, flavor, appearance, etc., for abnormal qualities. The milk is heated a second time at 104° to 106° F. Any abnormal coagulation of the milk is noted, such as holes due to gas. Gerber states that milk coagulating in less than 12 hours is abnormal, due either to the abnormal character of the milk itself or to improper care after being drawn. Milk that does not curdle within 24 to 48 hours is open to the suspicion of containing preservatives and should be examined for such substances."

Dirt test.—As recommended by Van Slyke and others a dirt test should also be made of market milk. A hand centrifuge has been placed on the market by several instrument makers. It has a speed much higher than the Babcock tester, sometimes 3000 to 8000 revolutions per minute. Electric power machines are also to be had. A true representative sample of the milk is taken and is whirled for several minutes. The sediment collects at the bottom of the tube and the percentage can be read by means of the scale. Simple settling and filtration methods have also been proposed for the estimation of the dirt in milk, but they give only approximate results.

Starch.—Occasionally starch is added to milk to give body. Starch grains with their concentric striations may be recognized under the microscope. Moreover if milk which has been adulterated with starch is heated to the boiling point and then cooled a blue color develops upon the addition of iodine.

Gelatine.—Stokes' test for gelatine as given by Kober is as follows: "Dissolve some mercury in twice its weight of strong nitric acid (sp. gr. 1.420); dilute with water to 25 times its bulk; to about 10 cc. of this solution add a like quantity of the cream and about 20 cc. of cold water; shake the mixture vigorously, leave it for five minutes; then filter. If much gelatine be present it will be impossible to get a clear filtrate. To the filtrate or a portion of it add an equal bulk of saturated aqueous solution of picric acid. If any gelatine be present a yellow precipitate will be immediately produced."

Coal-tar colors.—These "are detected by adding to the milk ammonium hydroxid and allowing a small piece of white wool to remain in it over night. The dye is taken up by the wool, which acquires a yellow tinge. When milk contains Martin's yellow, ammonium hydroxid intensifies the color and hydrochloric acid bleaches it."

Chromates.—Kober recommends Gucrin's method for detecting chromates. "To 5 to 10 cc. of milk add 2 drops of a 1 per cent solution of sulphate of copper and 2 or 3 drops of a freshly prepared tincture of guaiacum. Pure milk gives a greenish color, while milk containing 1 part in 100,000 of chromate will give an intense blue, which reaches its maximum in a few minutes."

Cream thickeners.—Various proprietary preparations have been put on the market for thickening cream or restoring its consistency, but most of these are based on the method of Babcock and Russell. This method consists in dissolving 2½ parts of cane sugar in 1 part of water, and 1 part of lime in 3 parts of water, after which the lime solution is strained into the sugar solution.

Testing Milk Products for Fat.

Condensed milk.—In using the Babcock test for determining the fat in condensed milk Van Slyke recommends that 9 gm. be poured in the test bottle, and and also 10 cc. of water and the usual amount of

acid. The test is made as for milk and the fat reading multiplied by 2. This method can not be applied to condensed milk containing cane sugar. In such cases Farrington recommends that 40 gm. of condensed milk be mixed with 100 cc. of water. Then 17.6 of this mixture is pipetted into the test bottle and 3 cc. of sulphuric acid added. The curd is brought into a lump by whirling at a high rate at a temperature of 200° F. The liquid portion is then poured off, 10 cc. of water and 3 cc. of sulphuric acid are added, the bottles whirled and the liquid portion poured off again. Then 10 cc. of water and 17.5 cc. of acid are added and the test made as with milk. The fat reading is corrected by multiplying by 18 and dividing by 7.

Butter, cream and cheese require special bottles indicating a greater range of fat percentage. Whey, skim milk and buttermilk require more care in reading the scale since the percentage of fat is very small.

Testing cream for fat.—An excellent set of directions for testing cream for fat percentage has been prepared by Webster and Gray and is given herewith.

"**Sampling:**

(1) Uniform composition and texture of cream is necessary.
(2) This is obtained by pouring from one pail or can to another.
(3) Frozen cream must be thawed before it can be sampled.
(4) Churned cream can not be successfully sampled.
(5) The tube sampler gives surest results.
(6) The dipper sampler does well if the cream is thoroughly mixed.
(7) Cream adhering to outside of tubes should not get into sample jar.
(8) The tube should be blown out with steam or rinsed with hot water before using each time.
(9) Keep the top of the tube open while it goes down, so it may fill as fast as lowered.

Keeping the samples:

(1) Sample jars must have tight-fitting covers and be kept tight.
(2) If cream is dried in bottles it is evidence that covers are not tight enough to prevent escape of moisture.
(3) Preservatives must be thoroughly mixed with cream; if too thick, heat the jars.
(4) Do not shake the bottle to mix the cream; give it a rotary motion.
(5) It is best to have samples protected from extreme heat or cold.
(6) Churned cream gives only approximate results; dried cream gives too high results.
(7) Extreme hot weather and lack of attention may cause separation of whey.
(8) Do not take too large samples; it is a waste of cream.
(9) Look after samples every day and see that they are in proper shape.

Preparing sample for measuring into test bottle:

(1) Sample must be absolutely uniform throughout.
(2) Heat sample to about 100°F., or until it is quite fluid.
(3) If sample is weighed, a much higher temperature may be used.
(4) Pour from one cup to another until uniform.
(5) The hotter the sample the more fluid it will be and the easier to make uniform.
(6) Take care that no cream remains in sample jar adhering to the sides.

(7) If sample is lumpy, press lumps through a fine wire sieve (such as is used for a teapot strainer).
(8) Melt any churned samples, mix, and sample quickly.
(9) Make things convenient for this work and see that it is thoroughly done.

Measuring into test bottle:

(1) Weighing the sample is the only method that will give correct results.
(2) Use delicate balances and keep them in perfect order.
(3) Test weights and scales for accuracy before using.
(4) Torsion balances are very accurate; weigh one test at a time.
(5) Less than 9 grams may be used, but 9 to 18 grams are more convenient.
(6) Air and gas bubbles in cream cause pipette tests to be inaccurate.
(7) Specific gravity of cream causes pipette tests of cream to be too low.
(8) Tables for correcting specific gravity are in use, but they do not correct for error caused by air and gas.
(9) Weighing corrects all difficulties due to specific gravity and air or gas in cream.
(10) Use great care to get the weights exactly right.

Making the test:

(1) If 18 grams of cream are used, add an equal weight of acid of 1.82 to 1.83 specific gravity.
(2) If 9 grams of cream are used, add an equal amount of water, then add acid as for 18 grams.
(3) Use enough acid to make a clear fat column; determine by trial.
(4) Use condensed steam or rain water for filling bottles.
(5) After adding acid, fill bottles at once to bottom of neck with water at about 120°F., and then whirl five minutes.
(6) Then add water of same temperature to bring fat within scale, and whirl two minutes.
(7) Keep the temperature down to 120°F. while whirling.
(8) Have a hole drilled in top of tester to insert thermometer.
(9) Run the tester at as high speed as bottles will stand.
(10) For hand tester put in boiling water when beginning the test till it nearly reaches the bottles.
(11) For steam tester raise the lid slightly while making the test.
(12) When through whirling keep tester closed, so as to maintain heat even as possible.

Reading the test:

(1) See that line between fat and water is straight, and read from bottom to extreme top of fat column.
(2) Read the depth of meniscus and deduct four-fifths of it from previous reading. A careful operator can estimate this.
(3) Add 0.2 per cent to the result.
(4) For 9-gram sample, double reading before adding 0.2 per cent.
(5) Read at a temperature close to 120°F.
(6) If bottles are placed in bath to regulate temperature, allow them to stand for fifteen minutes before reading.

The test bottles:

(1) Use as narrow-necked bottles as possible, to get wide divisions of scale.
(2) The 30 per cent 9-inch bottles graduated to 0.2 per cent are most accurate.
(3) Use 9-gram charge with these, doubling the reading.
(4) The 50 per cent 9-inch bottles are next in accuracy, graduated to 0.5 per cent.

(5) The 30 per cent, 40 per cent, and 50 per cent 6-inch bottles are too inaccurate in results.

(6) In wide necks the scale divisions are too close together and errors are more probable.

(7) All bottles should be tested for correctness of calibration.

(8) With cheap bottles nearly half are not correct.

(9) Bottles guaranteed correct can not all be depended upon."

In the above discussion chemical methods have been abridged as far as was safe. In all milk inspection practice the simplest methods are the ones to be used first. As a rule these are final except when doubtful results are given or litigation arises. For further details on chemical analysis and methods the inspector should consult "Dairy chemistry" by Richmond, "Dairy chemistry" by Snyder, "Modern methods of testing milk" by Van Slyke, "Testing milk and its products" by Farrington and Woll, "Milk and its relation to public health" Hygiene Laboratory Bul. 41, "Food analysis" by Leffman and Beam, "Foods and their adulterations" by Wiley, and, if familiar with German, also "Die Untersuchung landwirthschaftlich und gewerblich wichtiger Stoffe" by König, "Lehrbuch der Nahrungschemie" by Röttger and "Methoden der praktischen Hygiene" by Lehmann.

CHAPTER XII.

BACTERIOLOGY OF MILK.

Modern scientific investigation has made known the omnipresence and immense importance of bacteria in daily life. These micro-organisms have been shown by thousands of careful microscopic and bacteriological tests to be the direct and efficient cause of a great variety of changes in organic substances and of many diseases in man, other animals and plants. In scientific and popular literature relating to bacteria they are commonly referred to as germs, microbes, micro-organisms and bacteria.

Nature and Classification of Bacteria.

Bacteria are unicellular plants of microscopic size and constitute the lowest order of plant structures, standing in many respects on the border land between the animal and plant kingdoms. They consist of an internal substance known as protoplasm surrounded by a cell membrane and sometimes a thicker capsule. This membrane contains a modified form of cellulose similar to that found in the cell walls of higher plants. The capsule of bacteria in which this structure is recognized is apparently a thickened form of the bacterial membrane. Most plant cells contain a definite internal body known as the nucleus. Some dispute prevails at present on the point whether bacteria contain a nucleus or not. A number of bacterial organisms have been shown to possess an internal structure which at least closely resembles the nucleus of other cells. The size of bacteria is much less than that of the ordinary plant cell being in average cases about one twenty-five thousandth of an inch, but varying considerably in this respect.

The shape or form taken by various species of bacteria varies greatly and the classification of these organisms is based largely on the form and growth characters which they show under the microscope. Spherical bacteria are commonly called "cocci" or "micrococci," When these cocci occur in pairs they are known as "diplococci," when in chains "streptococci," and when in clusters like bunches of grapes "staphylococci." The individual elements of all these forms are of course spherical cocci, the terms "bacilli" and "bacteria" are also used for bacterial organisms and refer to the shape of the micro-organisms in question. Short rods are called "bacteria," while the rods of medium length are called "bacilli," and long filaments are referred to under the name of "leptothrix." The rods may not be straight and if definite twisted or coiled forms are assumed distinct names are given to them. For example, the slightly curved bacterial rod is known as a "comma bacillus," and the cork screw shaped rod of considerable

length as a "spirillum." Moreover the cocci may multiply by division in one plane forming a surface of spherical micro-organisms known as "planococci." When these cocci multiply in such a way as to form a mass with divisions in three dimensions, the organism is commonly called "sarcina."

With regard to the cell wall of bacteria, it is a colorless membrane similar in physical characters to that of the cell wall of higher plants but considerably less permeable to fluids and chemical substances. The cell wall under the microscope usually appears as a single line but in bacteria with capsules and relatively thick membranes the cell wall exhibits a double contour. The protoplasm in the interior of the bacterial cell shows granules, occasionally a structure resembling a nucleus, and other anatomical features which are to be found in higher plants.

Bacteria may be motile or non-motile. That is, under the microscope they may or may not show spontaneous movements. Cocci usually exhibit a continuous movement known as the brownian motion, which has not been definitely explained. Many bacteria exhibit spontaneous movements which are due to the lashing motion of flagella or minute hairs which proect outward from the cell membrane.

Reproduction.—Bacteria multiply by division or fission of the individual cells. Under favorable conditions of growth as soon as a cell has reached its normal size it divides into two by the formation of a cell membrane separating the two daughter cells. The different planes or directions in which the divisions or walls are formed determine the shape of the colony of bacteria and the disposition of the individual members of the colony. All plant and animal tissues multiply in essentially the same way but the process can be observed more easily under the microscope in the case of such simple organisms as bacteria. The time which elapses between cell divisions is in a large part dependent upon the conditions under which the bacteria are maintained. As a general rule the period is not over half an hour and in many cases may not be more than twenty minutes. If the average period is assumed to be thirty minutes it may be determined easily by a theoretical calculation that in twenty-four hours one single bacterial cell would produce 281,000,000,000 bacteria. As a matter of fact however the multiplication is never as rapid as such a theoretical calculation would show, for there are always some agencies which reduce the possible rate of multiplication. It is apparent however that under ordinary conditions not only the number of bacteria present in a suitable nutrient medium will increase enormously within a relatively short period, but also that the actual weight of the bacterial mass in such a medium will increase correspondingly. Certain species of bacteria, particularly cladothrix do not divide in the strict sense of the term but grow rapidly in length, giving rise to branched threads during this growth.

Bacteria exist not only in the ordinary condition of vegetative cells, multiplying by division, but also form spores and are able to reproduce themselves by these bodies. Bacterial spores in a physiological sense are to be compared with the seed of higher plants and by means of them bacteria are not only able to reproduce themselves but to protect themselves against unfavorable conditions which would be fatal to mere vegetative cells. The spores of bacteria are of two kinds, one known as endospores, which form inside the vegetative cell by the accumulation into a more or less spherical mass of a portion of the cell. The protoplasm in spores is apparently in a resting stage and is surrounded by a tough membrane which protects them against heat, desiccation, sunlight and antiseptic substances. In certain cases other kind of spores is formed and is known as "arthrospores." These are distinct from endospores by the fact that the whole vegetative cell becomes gradually modified into a spore by the formation of a thickened membrane and with a physiological modification of the contained protoplasm. The spores may be blown about by the wind, carried in dust or water and may lie in this way for an indefinite period provided favorable conditions for germination are not presented. As soon as the proper conditions for growth are found the spores germinate, producing ordinary vegetative cells which multiply in the ordinary manner as long as suitable conditions remain. The possible length of life of such spores under conditions not favorable for germination varies greatly in different species of bacteria but in the case of anthrax bacillus has been shown to be at least as long as eighteen years. Not all bacteria form spores. The cocci as a class are without spores but the bacilli and bacteria may or may not form spores. Among the spore-bearing bacteria familiar examples are found in the bacilli of anthrax, tetanus, malignant edema and black leg. Some of the bacteria which are commonly found in milk form spores while others do not. The spore-bearing bacteria are the ones which furnish difficulty in a successful pasteurization of milk.

It is apparent from the above considerations that there are much greater dangers from infection of milk or other food substances or from the mere presence of material containing spores in milking stables and milk rooms than from ordinary bacteria which do not form spores. The vegetative cells of bacteria are readily attenuated or killed by desiccation, the action of sunlight or a temperature of 150 degrees F. for a period of ten minutes or more. Momentary subjection of milk containing vegetative bacteria to a temperature at the boiling point is sufficient to kill these organisms. Spores on the other hand may resist a boiling temperature for several hours. In fact live steam at a temperature of 230 to 240 F may be required to kill them. With dry heat even higher temperatures are necessary.

Bacteria like other plants require a certain set of conditions in their environment in order to thrive and multiply successfully. They require for example the presence of certain elements which are recog-

nized as necessary to plant growth. These include oxygen, hydrogen, carbon, nitrogen, sulphur, phosphorus, potash, lime, magnesium and iron. Since bacteria do not possess chlorophyll they are not able to obtain their carbon directly from carbonic acid but depend upon the presence of carbohydrates, particularly sugars and starches. While the various plant foods mentioned above are necessary for the growth of bacteria, these micro-organisms cannot multiply in substances in which these elements exist in a too condensed form. Thus in thick sirups, condensed milk and similar products bacteria do not multiply even when inoculated into the material. As a rule bacteria thrive best in media which are neutral in reaction or which show a slightly alkaline reaction. A striking exception to this rule is seen in the case of lactic acid bacteria in milk which grow and multiply rapidly in the acid which they have produced by their own growth in milk. Other bacteria, however, which normally attack protein, cause its decomposition with the formation of gas, and are unable to multiply in milk strongly acidified by the presence of the lactic acid bacteria until after these organisms have completed their work and the acid content of the milk has diminished.

In addition to the presence of suitable food materials bacteria also require certain temperatures for their most rapid growth. In most cases the suitable temperature for the growth of bacteria may be said to range from 59° to 104° F, and the range is for the most part even narrower than that, being practically confined to 86° to 95°F. There are some bacteria, however, which may grow and multiply at 32°F., while a few others multiply even at a temperature of 140°F. Fortunately, however, the latter do not occur in milk. The figures just given for the temperature requirements of bacteria apply primarily to bacteria which do not cause disease. Pathogenic bacteria, on the other hand, require for the most part temperatures ranging from 95° to 98°F. for successful growth.

Bacteria may be classified into the two groups saprophytes and parasites, according as they draw nourishment from dead or living substances. Saprophytes are found in all kinds of dead and decaying animal and vegetable substances and are therefore to be met with in fertile soils and filth of all sorts as well as on utensils, cloths and other substances which have become contaminated with organic material. Parasitic bacteria, on the other hand, are found in some living organism or host. A few parasitic bacteria cause disease in plants but these have no significance in milk inspection. All other parasitic bacteria are known as pathogenic organisms for the reason that they cause disease in animals. Bacteria which are able to live only in dead organic material are known as "obligate saprophytes," and those which can live only in an animal body are known as "obligate parasites." Bacteria however which are ordinarily saphophytic but may also grow and multiply in living animal tissue are known as "facultative saphophytes," and pathogenic bacteria which may occasionally

live in dead organic substances are known as "facultative parasites."

Bacteria are furthermore divided into aerobes and anaerobes, according as they require the presence or absence of free oxygen in the nutrient medium for successful growth. Aerobic bacteria are unable to grow in the absence of oxygen, while anaerobic bacteria are destroyed by the presence of free oxygen. Some aerobes, however, may occasionally grow in the absence of oxygen and are known as "facultative aerobes," while certain anaerobic bacteria may grow in the presence of oxygen and are known as "facultative anaerobes."

The growth of bacteria brings about a variety of changes in the nutrient medium or any substance in which they may be found. Some of these micro-organisms produce fermentations, others light, still others color and a further important class produces gas. This variation in the effect of the growth of bacteria upon the nutrient medium into which they are inoculated is of great value in the recognition of different species.

As already indicated, bacteria like other plant organisms are subject to various influences which may affect their growth activities. As a rule the powers of resistance of bacteria toward unfavorable conditions are comparatively high, particularly in the case of those species which form spores. Brief mention has already been made of the effect of heat upon bacteria. It has been shown that spores are able to resist a dry heat of 266 degrees F. for one hour, and that for the certain sterilization of dry material contaminated with such spores a temperature of 350 degrees F. is required for half an hour. On the other hand nearly all bacteria without spores are killed by subjection to a temperature of 140 to 158 F. for a period of ten minutes. The great difference in the resisting power of bacterial spores and vegetative bacterial cells has suggested the adoption of the method of so-called fractional sterilization for destroying these organisms in milk and other substances. If for example, milk containing spore-bearing bacteria is subjected to a temperature of 150°F., all of the vegetative cells are destroyed, while the spores are unaffected. These spores however will germinate in the course of another twenty-four hours, at which time the material should be again subjected to a temperature of 150° for a period of ten minutes. The process is usually repeated for several days in order to make sure of complete sterilization. This method is in common use in the sterilization of nutrient media intended for inoculation with bacteria which are to be studied. It is based on the assumption, which has been proved to be correct, that by repeatedly applying heat at intervals sufficient to allow the germination of spores but not to permit the formation of new spores, the material may thus be rendered absolutely sterile.

Bacteria are not susceptible to the influence of cold. It is often popularly supposed that bacteria may be destroyed by extremely low temperatures. Such, however, has been found not to be the case. The Boston Board of Health has carried on a long series of observations

upon the bacterial content of water obtained from thawing ice. The bacteria originally present in water and caught in ice are not greatly affected by the freezing process and begin to multiply again vigorously as soon as furnished a satisfactory temperature for growth. By means of liquid air temperatures far below those which ever occur in nature have been produced and bacteria have been subjected to these extremely low temperatures without thereby losing their vitality. It is apparent, therefore, that freezing temperatures cannot be considered as having any antiseptic effect upon ordinary bacteria.

Direct sunlight exercises a marked effect in attenuating or destroying bacteria. In fact sunlight is one of the very best and most efficient antiseptic agents which can be applied to stables or other structures which it is desired to disinfect. It is generally stated that the effect of light is not fully exercised if the bacteria exist in masses of filth of considerable size. Recent experiments, however, have shown conclusively that within reasonable limits the size of particles of filth, sputum or animal material in which bacteria are found has no appreciable effect upon the influence of sunlight in destroying or attenuating the bacteria. It has become more and more obvious in recent years that stables so constructed as to permit the free access of sunlight may be safely assumed to be more sanitary, even if the ventilation is poor, than stables in which the ventilation is good but the lighting arrangements poor.

The influence of pressure upon bacteria is very slight indeed. Experiments have been made in which anthrax bacill and other micro-organisms have been subjected to pressures as high as 6000 atmospheres without killing them or appreciably affecting their vitality.

The effect of X-rays upon micro-organisms has been recently quite extensively tested in connection with the attempted cure of various diseases, particularly tuberculosis, typhoid, cholera, diphtheria, anthrax, rabies, etc. The results obtained in these experiments are not in harmony. A few investigators have claimed remarkable effects from X-rays in the destruction of bacteria lying at considerable depths underneath the skin of the living body. This is particularly true in cases of lupus. It is impossible however to make any practical use of X-rays in dairying, even if this agent should be proved to have an important antiseptic effect.

For twenty years or more experiments have been carried on with electric currents in sterilizing water, milk and other liquids. Averaging the results obtained with 660 samples of milk, Petersen found the electrical resistance of milk to be 232 ohms. Boult and Dubousquet-Laborderie in 1892 and 1893 studied the question of sterilizing milk by electricity. They found that an alternating current had no effect upon the bacteria in milk. A continuous current was said to destroy all the bacteria on account of the heat developed by the electric current,

but some electrolysis of the milk took place. The process was patented in 1893.

Drown and others found the purification of water by electricity to be impracticable. Willson patented in 1906 a process for separating the casein by electroylsis.

Recently a process for sterilizing milk by electricity has been patented by Goucher. A number of machines made by this company are already in use, one having been purchased in Honolulu. In the circulars sent out by the Goucher Electric Purifying Co., the claim is made that "the milk is brought to a state of absolute sterility" and that "its digestive properties are enhanced to the maximum." In a report of the Lederle Laboratory on milk purified by the Goucher process it is stated that the milk on issuing from the machine has a temperature of 155°-161°F., and that an alternating current is used of 1920-1960 voltage and 7.5-8.5 amperage. In one test milk containing 2,970,000 bacteria per cc. showed 172,000 bacteria per cc. after being "purified." In another test the bacteria in raw and "purified" milk was 2,700,000 and 58,000 per cc, respectively, and in a third 520,000 and 18,000. It is stated that nearly all of the tubercle bacilli and streptococci, 97 per cent of the staphylococci and 98.8 per cent of the typhoid bacilli were killed by electric purification. Better results may be obtained in the future but the old adage that "pure milk is better than purified milk" is still true. The results given by this machine at present are highly satisfactory.

Bacteriologists have made experiments to determine the effect of mechanical shock by the production of currents and other mechanical movements in media containing bacteria. The results obtained from these experiments are somewhat antagonistic. Certain species of bacteria appear to thrive best in media which are completely at rest and are considerably checked in their development when the media are shaken or subjected to other mechanical movements. Thus in one experiment the continued shaking of a culture containing Bacillus subtilis for four days was sufficient to destroy the bacteria. It is unnecessary to discuss in this connection the effects of chemical antiseptics upon bacteria. Many of these are known to exercise a powerful effect upon the bacteria, destroying them even when used in diluted solutions. This matter has been discussed in chapter III in connection with an account of the disinfection of stables after the prevalence of infection diseases. The disinfectants commonly used for destroying bacteria are corrosive sublimate, formalin, carbolic acid, lime, copper sulphate, permanganate of potash, borax, etc. Disinfectants, however, cannot be used in milk on account of their harmful properties in human beings. The conclusion has been repeatedly reached in discussing this matter from different standpoints that when proper precautions are observed milk may be drawn with only an exceedingly small number of comparatively harmless bacteria in it. If the milk is then cooled to a temperature of 40°F. and kept at a low temperature

until consumed, the few bacteria present in it when drawn will not have an opportunity to multiply. If, on the other hand, on account of carelessness or accident the milk becomes contaminated, the only permissible means of sterilizing it is by the application of heat.

Sources of Bacteria.

Normal udders.—As shown by Conn and various other investigators of dairy problems, milk is secreted in the normal udder entirely free from bacteria. Numerous investigations in recent years have demonstrated the truth of this statement, although it has been many times doubted on account of the great difficulty encountered in obtaining perfectly aseptic milk from the udder. At first various attempts were made to drawn milk from the udder under sterile conditions so as to permit of no contamination from external sources. Although many of these attempts were failures, success was had in many instances and enough proof has been adduced to show that milk at the moment of its secretion in the secretory tissue of the udder of normal cows does not contain bacteria. In other words the healthy udder does not secrete bacteria with the milk and we are therefore forced to the conclusion that all bacteria which find their way into the milk of healthy cows must come from outside sources. Attention has already been called to the fact that the udder may be invaded to a greater or less depth by bacteria which gain entrance from the outside. In order to determine the extent of this invasion the utmost precautions must be taken to prevent the introduction of bacteria with instruments used in obaining samples of milk from different parts of the udder. This matter has been thoroughly investigated by Ward, Grotenfelt, Freudenreich, Moore and many others. Ward made a study of the lactiferous ducts of 19 cows and found them to contain bacteria throughout their whole length. It was shown during this investigation that milk is sterile when secreted by the mammary glands of healthy cows but may at once become contaminated by bacteria which are always present in the smaller milk ducts of the udder. In Ward's investigations the bacteria found in the interior of the udder were not such as affect milk seriously. This fact however gives us no assurance that injurious or pathogenic bacteria may not make their way into the udder. The fact that the udder is constantly and normally invaded by various bacteria gives a basis for the ordinary classification of a number of bacteria in the group of dairy bacteria. There are apparently no structures in the udder which are adapted to preventing the invasion of bacteria from the outside through the milk ducts of the teats.

Diseased udders.—While it is true that non-pathogenic bacteria such as may be present in enormous numbers in the alimentary tract of cows are not secreted through the udder, the case is quite different when we come to consider pathogenic bacteria which may affect cattle, particularly those micro-organisms which cause abnormal conditions

in the udder. It is impossible to make any general statement which would hold true regarding the possible excretion of all forms of pathogenic bacteria from the udder. As indicated in chapter XIII on the transmission of infectious diseases by milk not all disease germs which affect cows have been demonstrated in the milk of affected cows and those which are found in milk are not all excreted to the same extent. Tubercle bacilli are found from time to time in the milk of tuberculous cows. This is especially the case whenever the udder contains a local lesion of the disease. In all such instances the milk commonly contains tubercle bacilli, while in other cases in which the udder is not involved the milk may or may not contain tubercle bacilli according as the disease progresses. Apparently whenever a tubercle in any part of the body breaks down and the tubercle bacilli are thus set free into the lymph or blood, these organisms may be carried through the udder and may there escape into the milk, especially if there be a mixed infection. The probability of disease germs being found in the milk is greatest in the case of all diseases in which hemorrhagic processes occur. Thus in anthrax the probability of the bacilli being excreted with the milk is very strong. Similarly with hemorrhagic septicemia. Even in the case of tetanus and rabies the virus of the disease might readily escape into the milk if any abnormal condition of the udder should exist at the same time with the primary disease. In the case of actinomycosis of the udder the ray fungus which causes the disease might easily escape from a tubercle and find its way into the milk. In nearly all cases of foot and mouth disease in which the udder is affected the virus gains entrance to the milk and renders it highly infectious and dangerous. Garget or mammitis is a very common trouble among milk cows and the milk in cases of this disease is almost sure to contain the specific micro-organism, if the disease is of the infectious form, or if other bacteria along with pus and disintergrated tissue are set free during the course of the disease.

Exterior of cows.—As soon as milk is drawn it is subject to far greater likelihood of infection with bacteria of various kinds than could be the case while it was still retained in the udder. One of the most fertile sources of contamination of milk with bacteria is the cow herself. Some of the practical considerations in this connection have already been discussed in chapter VI on milking and handling of milk on the farm. The skin and hair of the cow must be considered as perhaps the most important source of contamination of milk for the reason that these parts are continually exposed to bacterial pollution as the result of the various forms of filth which are almost always attached to the cow and her hair. If the skin and hair of cows were contaminated but once and the moist filth on these parts were allowed to become thoroughly desiccated and exposed to sunlight without fresh contamination, the bacteria in the filth would soon be destroyed or become so attenuated that they could scarcely cause ser-

ious changes in milk. In practice, however, this never occurs. Cows are exposed to fresh contamination many times daily. Every time they lie down a certain amount of dust, straw or manure becomes attached to the hair and skin, and more bacteria are thus placed in a favorable position for falling into the milk at milking time.

Obviously there is no limitation upon the kind or nature of bacteria which may be found on cows. The variety and number will depend in every case upon the cleanliness of stables and yards and the care exercised in cleaning cows. These bacteria may include not only the ordinary milk bacteria which produce fermentation, change of color, gas and other products, but also any pathogenic organisms which may be present as the result of disease. If cows are handled by attendants who have recently recovered from infectious diseases or who come in contact with patients suffering from such diseases the pathogenic micro-organisms may be transferred to the cow in such a position as to fall into the milk. Moreover, according to recent investigations of the Bureau of Animal Industry it appears that tubercle bacilli are almost always present in the manure of tuberculous cows. They find conditions in manure under which they may retain their vitality and virulence for long periods and it seems highly probable that a considerable percentage of the tubercle bacilli found in milk may have gained entrance to the milk by being first excreted in the manure in which they become plastered upon the cow to fall into the milk at some time later.

The air.—The lower strata of air always contain varying numbers of bacteria of different sorts. The air of cities contains more than that in the country and the air of stables and yards more than that over cultivated fields and in forests. If dusty feeding stuffs are given to cows at or near milking time the air becomes laden with a quantity of dust particles carrying bacteria of various kinds. These may easily find their way into milk under the ordinary conditions which prevail on dairy farms. Moreover the bedding is almost always contaminated with a large number of bacteria, and, if dry and fine, the movements of the cows and attendants are almost sure to stir up sufficient dust to keep the air highly contaminated with bacteria. Again, in view of the fact just mentioned that tuberculous cows secrete bacteria in the feces, this material when dry is certain to add its quota to the contamination of the air. Obviously the contamination of milk with such bacteria is a far more serious matter than in the case of ordinary milk bacteria.

The large diameter of ordinary milk pails exposes a large surface of milk to contamination with bacteria from the air. The extent of exposure from this source during milking cannot be better diminished than by the use of covered pails as mentioned in chapter VI. Fortunately the micro-organisms usually found in the air of sanitary stables belong to species which have no serious effect on milk and are therefore relatively of secondary importance. A comparative test

was made by Fraser in which agar plate cultures were exposed in different locations to determine the number of bacteria which would fall upon their surfaces during different lengths of time. The average time of exposure was half a minute. In these experiments more than a thousand exposures were made in different locations and the average results obtained indicate that the number of colonies of bacteria which find their way into dishes exposed under such circumstances with an area of 63 square centimeters is highest under a comparatively clean but unwashed udder and lowest in a sanitary milk bottling room. The other locations compared with these were an open field, a barn yard, a well kept commercial barn, a university dairy barn, a poorly kept barn, under a washed cow's udder and in a dairy room. The effect of feeding roughage and brushing the cows shortly before milking was merely to increase the number of bacteria. The results obtained in these experiments showed that the greatest source of contamination in milk is the cow herself, particularly the udder. The number of bacteria falling upon a given surface was greatly reduced by an ordinary washing of the udder.

The milker.—Attention has already been called in chapter VI to the necessity of employing milkers with sanitary personal habits and with a thorough understanding of the importance of cleanliness in handling milk. The bacteria which the milker may contribute to milk depend entirely upon his habits and upon the persons and objects with which he comes in contact. His hands and clothes may be contaminated with the ordinary bacteria of the air and soil which cause relatively little serious trouble in milk. On the other hand a careless or insanitary milker may carry with him not only the micro-organisms which cause disease in animals but particularly the bacteria of typhoid, diphtheria, scarlet fever, cholera and other infectious diseases of man. In this connection it should be remembered that in general the bacteria which gain entrance to the milk from the clothes or person of the milker are more likely to be dangerous than those which come from the exterior of the cow and from the air.

Milk utensils.—Pails, separators and all utensils used in handling milk serve as fruitful sources of contamination if they are not thoroughly cleaned after each using. If milk particles are allowed to remain upon the surface of such utensils they may not only contain the bacteria present in the milk which they held at a previous using but may also serve to catch and hold bacteria which may gain entrance to such utensils between two usings. The bacteria which may thus be added to milk from unclean utensils may include not only the ordinary milk bacteria but various pathogenic micro-organisms.

Stables.—In ordinary cases the stable is a source of bacterial contamination of milk only in an indirect sense in that the bacteria of stables may become attached to the cows from which they fall into the milk or may be raised in the dust of the stable and gain entrance

to the milk through the air. Obviously a large part of the bacterial contamination of milk from the exterior of cows and from the air may be prevented by careful sanitary attention to the condition of stables.

Barnyards.—The relationship of barnyards to the bacterial contamination of milk is essentially the same as that of stables. They may tend to add bacteria to the milk as the result of the filth which becomes plastered upon the cows, or as the result of the dry contaminated dust which may be blown from such locations into the milking stable. If barnyards are properly cleaned and drained, the amount of possible bacterial contamination which they contain will be greatly reduced.

Bedding.—One of the essential prerequisites in a sanitary bedding is that it shall not be dusty and shall not be capable of being ground up into a fine condition. Moreover it should absorb and hold liquids. All moldy, smutty or dirty straw of other material is unsuitable for use as bedding in a dairy stable. Corn stalks, shavings, sawdust and peat moss are satisfactory materials for bedding and contain relatively little dust or filth which can give rise to bacterial contamination of milk.

Water.—Nearly all water ordinarily used about cow stables and in milk rooms contains a certain number of bacteria. Spring water and water from deep wells properly protected against the reception of surface drainage have far less bacterial contamination than water which has not been filtered through the soil. The presence of ordinary bacteria in the drinking water of cows is of itself no source of contamination to the milk, since such bacteria do not penetrate through the walls of the alimentary tract and therefore cannot gain entrance to the milk directly through the cow. If unsterilized water, however, is used in washing milk vessels, these utensils may become contaminated and may give rise to the infection of milk subsequently poured into them. A number of outbreaks of typhoid fever have been traced directly to the use of contaminated water in washing milk utensils.

Contamination in handling.—The possibility of contaminating milk with bacteria continues until the milk is consumed. The less handling to which the milk is subject in open vessels, therefore, the less liability of contamination. If milk is poured from one vessel to another in the open air, there is not only the possibility of contamination from the air, but from particles of dust or filth which may be shaken from the clothing of the person who handles the milk. Moreover with each transfer of the milk from one vessel to another there is the added chance of an unclean milk utensil adding its quota of bacteria to the milk. If the milk is strained, cooled, bottled and sealed as quickly as possible and delivered to the consumer in bottles, the danger of contamination is much less than when it is carried in cans which are opened from house to house and exposed to further bacterial pollution.

Germicidal Action of Milk.

The results obtained by various investigators in studying the bacteriology of milk indicate, as stated by Stocking, that by far the larger part of bacteria found in milk gain access to it through external sources. Milk undergoes souring, changes in flavor, odor and color and various processes of decomposition as a result of the presence and growth of these bacteria. It has long been a generally accepted opinion that nearly all spores or bacteria which may find their way into milk, thrive and multiply in milk at a rate which depends primarily upon the temperature of the milk. It is also commonly believed that these bacteria begin to multiply as soon as they gain entrance to the milk and with great rapidity. This has been considered as the prime reason why milk should be cooled as soon as possible after being drawn. The assumption of the rapid multiplication of all bacteria in milk was somewhat thrown in doubt by the experiments of Hunziker, in 1901, and subsequent experiments by other investigators. As a result of these studies it was announced that milk exercises a germicidal action upon bacteria which persists for a certain number of hours after it has been drawn. Careful experiments, the accuracy of which cannot be doubted, indicate clearly that the number of bacteria in milk actually does diminish for a number of hours after it has been drawn until the bacterial contamination reaches a minimum, after which the number of bacteria begins to increase rapidly. The supposed germicidal action was found to be most rapid at relatively high temperatures and under such conditions the minimum number of bacteria was reached in a few hours. If the milk was held at a lower temperature the intensity of the bactericidal action was less and the number of bacteria gradually diminished for a much longer time. Under ordinary conditions there was found to be a diminution in the number of bacteria for three to nine hours after the milk was drawn.

The question of the germicidal action of milk has been thoroughly studied by Conn and Stocking, with the results that the facts announced by Hunziker and others are found to be correct, but these facts receive a different explanation than that proposed by Hunziker. In the recent investigations by Stocking it appears that while milk a few hours old contains a smaller number of bacteria than it did when first drawn from the cow, this is due to the relative adaptability of different species to continued growth in milk. Some kinds of bacteria find milk a very unfavorable medium in which to grow and Conn and others have shown that milk at the curdling point contains relatively few species of bacteria, frequently only two or three. This means that nearly all of the species of bacteria have disappeared. Some of them can not grow in milk and disappear very soon after finding their way into it. Other species grow slowly but gradually disappear. A few other kinds of bacteria find milk a very favorable medium and multiply quite rapidly. It is easy to

understand, therefore, that the death and disappearance of the majority of species of bacteria in milk might for some time more than counterbalance the multiplication of the few species which naturally thrive in milk. This would account for the gradual diminution of the total number of bacteria in the milk for a limited time without making the assumption of any germicidal property of milk. Accordingly Stocking recommends the continuance of the practice of immediately cooling milk in order to hold in check the multiplication of the typical lactic acid bacteria which may be expected to and actually do increase from the moment in which they gain entrance to the milk.

Classification of Milk Bacteria.

Several attempts have been made to classify into more or less natural groups the bacteria which have been found in milk. On account of the uncertainty which still prevails regarding the classification of bacteria in general and the significance of species among bacteria, such attempts have sometimes been considered premature. Systems of classsification of milk bacteria may be rather artificial, but at any rate are of use in a practical way in the separation and study of different forms with special regard to their relative harmfulness and the various effects which they produce in milk. Perhaps the most extensive and successful attempt at a workable classification of milk bacteria has been made by Conn and the results which he and his associates have obtained have been freely utilized in the following paragraphs.

The bacillus lactis acidi group.—When grown on litmus gelatine the organisms of this group appear as small opaque colonies under the surface, with spines at the edge and of a red color surrounded by a red halo. This type is the most universally distributed of all the lactic acid bacteria and shows considerable variation in its power of curdling milk. Sometimes the milk is curdled rapidly, sometimes slowly and occasionally not at all. A small subgroup of the *Bacillus lactis acidi* type differs from the typical form in producing exceedingly small colonies on litmus gelatine, transparent and commonly invisible to the naked eye. It is less acid than the typical form and the spines at the edge of the colony are wanting. This form is rarely found in fresh milk, but appears to be common in milk kept for some time, especially if maintained at relatively high temperatures.

The Bacillus lactis aerogenes group.—The name adopted for this group is that of the typical species which is non-motile, produces lactic acid, does not readily curdle milk and ferments milk sugar with the production of gas. On litmus gelatine the colonies are of fair size, appear both under and on the surface and surrounded by a bright red ring. The acid ring is much more striking than in the bacillus lactis acidi group. The acid reaction is most striking at first. After several days the red color disappears and the litmus turns blue. Some

colonies which are to be classified in this group prove to be *Bacillus coli cummunis.* Occasionally colonies of bacilli are found which produce acid but do not appear to agree well with the characters of the groups of lactic acid bacteria mentioned above.

Streptococcus group.—The colonies of this group are not characteristic, being opaque, small and round if under the surface, but spreading over the surface to form a white mass. The reaction is never acid and rarely alkaline. At least four species of streptococcus are to be placed in this group and a number of bacilli are also classified with them on account of their action on milk. While most of the characters are negative this serves in an entirely satisfactory way to differentiate the group. None of the species produces enzymes, putrefaction or any visible changes in the milk, and the colonies are neutral in reaction. The organisms belonging to this group may be found in the milk ducts and are in all cases most abundant in fresh milk, disappearing in large part in older milk when the lactic acid bacteria have multiplied in abundance.

Yellow coccus group.—The organisms of this group produce yellow colonies both below and on the surface of litmus gelatine. There are apparently two types of microorganisms in the group, one producing acid and the other not, while neither curdles milk. The effect of the growth of these organisms on milk is very slight. Most of the microorganisms are micrococci, while some appear to be sarcina.

Rapid liquifying group.—The bacteria included in this group are characterized by the fact that gelatine is rapidly liquified. A single colony will liquify a whole gelatine plate in two or three days. All of the organisms belonging to the group are decidedly putrefactive and if present in large numbers cause very undesirable changes in the milk. Fortunately they are rarely numerous in milk, but strongly antagonized by the presence of lactic acid bacteria so that they gradually disappear in old samples of milk. The presence of bacteria belonging to this group, the commonest species of which are *Bacillus fluorescens liquefaciens* and *Bacillus subtilis*, furnishes difficulty in all bacteriological examination of milk for the reason that the gelatine may be completely liquified before colonies of other bacteria are ready for study.

Slow liquifying group.—A number of organisms have been grouped together by Conn under this head for the reason that they liquify gelatine very slowly, often producing only small pits after a week's growth. Their presence on a gelatine plate, therefore, does not greatly interfere with the study of colonies of other bacteria. Like the rapid liquifying bacteria they are most numerous in fresh milk, being displaced by lactic acid bacteria as souring takes place. All of the organisms of the group produce enzymes and cause a greater or less amount of putrefaction. These organisms do not come from the milk ducts and their presence in a sample of milk should render the

milk somewhat suspicious. It indicates at least a carelessness in handling milk since they must have gained their entrance to the milk in filth from the outside.

The bacteria which occur in milk may also be roughly classified into two general groups according as they are saphophytes or parasites. The parasitic bacteria are in many respects of most importance in milk for the reason that they are pathogenic or produce disease in man and animals. In the following paragraphs descriptions are given of the morphological characters, biology and behavior of the pathogenic and saprophytic bacteria commonly found in milk. The descriptions of the pathogenic bacteria are compiled from numerous original sources, including Swithinbank, while descriptions of the ordinary bacteria are condensed from those given in the excellent classification of milk bacteria by Conn in the 18th report of the Storrs Agricultural Experiment Station.

Pathogenic Bacteria Most Frequently Found in Milk.

Bacillus tuberculosis Koch.

Morphology.—Slender, slightly bent, pointed ends, sometimes threads and branched forms, or club forms, longer in milk than in tissues, occurring singly or in twos, threes or colonies. Size 1.5-4×.4m*. Acid—fast. Gram and Ziehl-Neelsen stains positive. No spores or flagella. Non-motile. Capsule stains. Bouillon.—Growth in 7 or 8 days if glycerine is added. Sometimes pellicle. Glycerine-agar.—Growth begins in 6-12 days. Colonies minute, whitish-yellow, later brown, lichen-like, elevated, sinuate, dry or moist. Potato.—Decided growth in 2 or 3 weeks, best if potato is moist, small crumb-like masses, friable, yellow, dull. Blood serum.—Growth begins in 10-12 days. Serum not liquefied. Colonies light, dry, crumb-like coalescing scales. Pathogenic for man and other animals. Aerobe.—Growth from 22°-42 C., but best at 37°C.

B. typhosus Eberth.

Morphology.—Takes ordinary stains. Gram stain negative. Short, plump rods, longer in cultures. Size 1-3×.6-.8m. Capsule. Motile, 8-14 long flagella. Occurs in threads. Serpentine movements. Vacuoles in stained and unstained preparations but no spores. Bouillon.—Turbidity, abundant sediment. Gelatine plates and tubes.—Small, yellowish-white, punctiform, raised center, wavy elevations under microscope. In stab cultures granular, grayish-white thread growth. Streak cultures similar, non-liquefying. Agar plates and tubes.—Colonies irregular, round, grayish-white, slightly raised, yellow lines extending outward from the center. In stab cultures granular, grayish, thread growth with irregular outline and oily lustre, later yellow. On streak cultures spreading, wavy, smooth edge, shiny. Milk.—Appearance unchanged, not coagulated, slightly acid. Potato.—Variable. Delicate and moist, grayish or rarely brownish. May be readily differentiated from **B. coli** by the fact that the latter coagulates milk within 48 hours with abundance of acid. **B.** typhosus grows best as aerobe but also as anaerobe and in CO . Produces typhoid fever in man and a fatal intoxication in animals. Grows best at 37°C. on all ordinary media, less well on non-albuminous media. No pigment nor indol. No gas in lactose.

B. diphtheriae Klebs-Loeffler.

Morphology.—Slightly curved rods usually with one end club-shaped and the other pointed, or may be short wedge shaped, comma shaped, or dumb-

* m=micron.

bell form. Size 1.2-2×.3-.5m.* In groups of 2-4, no long chains. Stained by aniline dyes. Gram, Loeffler and Nicolle. Capsule. No flagella. Non-motile. No spores. Bouillon.—Dust-like granules, usually pellicle. Produces indol, acid and nitrites. Gelatine.—Yellowish-white, slightly elevated surface, non-liquefying, non-characteristic. Agar plates and tubes.—In 24 hours circular, round, white elevated colonies with smooth edges and moist. Potato.—Little or no growth if acid, scanty after a few days of alkaline. Milk.—Abundant growth, amphoteric reaction, no curdling. Blood serum.—Rapid at 37°C. Characteristic within 12 hours, round, raised, grayish-white colonies, yellowish, translucent if young, moist, margin irregular, center thickened and opaque. Colonies not confluent, may reach size of 4 or 5 mm. Abundant growth on hen's eggs. Grows best at 37°C. Quickly killed at 60°C. Aerobe.

B. enteritidis sporogenes Klein.

Morphology.—Sometimes in chains. Size 1.6-4.8×.8m. Takes aniline dyes and Gram stain. Motile. Spores polar, not seen in milk cultures. Gelatine. —Good growth on glucose gelatine, gas, liquefaction. Agar.—Grows well in glucose agar with much gas. Deep colonies white by reflected light, brown by transmitted light. Surface colonies flat, circular, moist gray, appearing in 24-48 hours. Milk.—After 36 hours at 37°C. the cream at surface is separated by stringy, pinkish masses of coagulated casein containing gas. The whey is acid and contains numerous bacilli. Anaerobe. Causes death in guinea-pigs within 18-24 hours.

Streptococcus of contagious mammitis.

Morphology.—Long, undulating chains, elements 1m* in diameter, shorter in old than in recent cases of mammitis. Aerobe or anaerobe. Takes aniline dyes but Gram stain poorly. Gelatine.—Small, translucent, whitish colony. Pellicle. Potato.—Poor growth. Bouillon.—Growth after 24 hours. Sediment, no turbidity. Milk.—Rapid growth, curdled in 24-48 hours, strongly acid. Causes mammitis in cows and goats. A smaller form causes gangrenous mammitis in sheep. Possible cause of streptococcic sore throat in children.

Staphylococcus pyogenes aureus.

Morphology.—Round small cocci in masses .8m* in diameter, singly or in pairs, masses, or grape-like clusters. Takes ordinary stains. No flagella, non-motile. Bouillon.—Marked turbidity, sediment, pellicle. Agar.—Round, even margin, orange, granular. In stab culture feeble deep growth, good surface growth, smooth, shiny, orange. Similar growth in streak cultures. Potato.—White, then yellow, raised, shiny, later orange and dry. Milk.—Acid, complete curdling in 1-8 days. Grows as an aerobe, less well as an anaerobe, pigment only in presence of oxygen. Grows best at 37°C. Causes suppuration in man and animals. The varieties albus and citreus are very similar except for forming white and yellow pigments respectively.

Streptococcus pyogenes Rosenbach.

Morphology.—Chains of cocci, longer in fluid than in solid media. Takes ordinary stains and Gram. Mucoid capsule. Bouillon.—Sediment, sometimes turbidity, no indol. Gelatine.—Small, white, round, flat, slow, smooth margin. Agar.—Small, white, granular, sometimes lobed. Gray, irregular surface in stab cultures. Potato.—Absent, invisible or rarely abundant. Facultative anaerobe. Grows best at 37°C. Pathogenic for laboratory animals, causes erysipelas and suppuration in man.

Streptococcus scarlatinae Klein and Gordon.

Morphology.—Polymorphic streptococcus with all transition stages between coccus and bacillus. Coccus form prevails in bouillon, bacillus on agar. Takes simple stains and Gram. Bouillon.—After 24 hours at 37°C. a single, coherent, white-gray mass appears at base of tube, floating as a flat conglomerate in the fluid medium. Gelatine.—Slow, small, gray, circular, firm edge. No liquefaction. Chain formation conspicuous. Agar.—After 24 hours colo-

nies are gray, granular, irregular, tuberculated; or similar without tubercles; or with a frill of chains around a compact center. Milk.—Rapid curdling, acid. Blood serum.—Good growth of colonies. Aerobe. Found in cases of scarlet fever and sometimes thought to be the cause of the disease. Occurs also in diseased udders of cows. Pathogenic for mice and rabbits.

Spirillum cholerae asiaticae.

Morphology.—Curved rods with rounded or pointed ends. Size .8-5×.2-.5m.* Often S-form. Singly or in chains. Stains by ordinary methods but not by Gram. Granules but no spores, motile. Gelatine.—After 24 hours at 20°-22° C. small, discoid, white colonies, granular, irregular border. Gelatine stab.—Clavate mass after 2 days. Potato.—Poor growth unless potato is alkaline, yellow or brown, thick streak.—Bouillon.—Rapid, little turbidity, pellicle. On peptone bouillon the colonies are colored red by the addition of a few drops of sulphuric acid. Does not live long in milk after it has begun to sour, but thrives well in pasteurized milk. Causes Asiatic cholera in man.

Micrococcus melitensis.

On litmus-glucose-nutrose-agar plates a dense crop of colonies appears after 3 days. Good growth on agar slope after 2 days at 37° C. Colonies are small, circular and bluish. On litmus-milk growth is alkaline. Found in the blood and milk of goats affected with Malta fever, and causes the same disease in man with symptoms resembling those of typhoid fever.

Many other pathogenic bacteria may occasionally or acidentally gain entrance to milk, but this happens so rarely that no good purpose would be served by describing all of them in this connection. For a further discussion of the transmission of contagious diseases by milk consult Chapter XIII.

Descriptive List of Ordinary Milk Bacteria.

A. NON-LIQUEFYING COCCI. STREPTOCOCCI AND MICROCOCCI

I. Types That Do Not Produce Acid.

M. lactis rosaceus Conn.

A pink micrococcus. Morphology.—.8m.* in diameter. Stains by the Gram method. Gelatine colony.—1 mm. in size, with a nucleus and a light outer zone. On litmus gelatine a bluish colony, not acid. Gelatine stab.—A needle growth and spreading pink surface. Agar streak.—A luxuriant pink growth. Fermentation tubes.—No acid nor gas in sugar bouillon and no growth in closed arm. Bouillon.—Sediment and turbidity but no pellicle. Milk.—Rendered slightly acid, with pinkish sediment, becomes somewhat slimy. Potato.—Luxuriant, thick, pink growth. Grows at both 20° and 37°C. Aerobic.

M. lactis citreus B. Conn.

Yellow nonacid coccus. Morphology.—Size .8m.* No chains. Stains by the Gram method. Gelatine colony.—Round, yellow surface, 1 mm. in size. Gelatine stab.—Good needle and surface growth. Agar streak.—Luxuriant growth. Fermentation tubes.—No acid or gas in sugar bouillon and no growth in closed arm. Bouillon.—Abundant sediment and sediment and thin pellicle. Milk.—Rendered slightly acid but not curdled at both 20° and 37°C. Potato.—Abundant canary-yellow growth, potato discolored. Grows well at 20° and 37°C. Aerobic.

M. lactis flavus Conn.

An orange non-acid micrococcus. Morphology.—Size .5-.8m.* Stains by the Gram method. Gelatine colony.—Round, smooth, thick, homogeneous orange. Gelatine stab.—Good needle and surface growth, orange. Agar streak.—Luxuriant, moist, smooth, orange or red-brown. Fermentation tubes.—No acid or gas in sugar bouillon, nor growth in closed arm. Dextrose and lactose may be made alkaline. Bouillon.—Sediment, turbidity and pellicle, or

both latter wanting. Milk.—Acidified at 20° and 37°C. Potato.—Moderate, smooth, moist red-brown to orange. Grows at 20° and 37°C. Aerobic.

M. lactis citreus Conn.

A slimy micrococcus. Morphology.—Size .8-.9m.* Gram stain positive. Gelatine colony.—Thick, round, smooth, white, turning green. On litmus gelatine coarse. Gelatine stab.—Vigorous needle and surface growth. Agar streak.—Thin, spreading, white. Fermentation tubes.—No acid or gas in sugar bouillon nor growth in closed arm. Bouillon.—Sediment and turbidity but no pellicle. Milk.—No change except sliminess. Potato.—Thick, slaty gray growth turning blue or black, potato being discolored. Grows well at 20° and 37°C. Aerobic.

M. lactis arborescens Conn.

Morphology.—7m* in diameter. Gelatine colony.—Myceloid, 1 mm. in size, sometimes smooth. Gelatine stab.—Arborescent needle growth and a surface growth. Agar streak.—Luxuriant, smooth, moist, white. Fermentation tubes. —Probably no acid nor gas. Bouillon.—Turbidity, sediment and pellicle. Milk.—No action or slight alkalinity. Potato.—Spreading, brownish not luxuriant. Grows at 20° and 37°C. Aerobic.

Galactococcus versicolor Lux.

White non-acid. Morphology.—Streptococcus. Size .5-1.5m.* Gram stain usually positive. Gelatine colony.—Spreading, white, yellowish or brownish, thin. Gelatine stab.—Abundant needle and surface growth. Agar streak.—white to yellowish, moist. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity but no pellicle. Milk.—No action or slight acidity. Potato.—Scanty, gray-white or no growth. Grows at 20° and 37°C. Aerobic. Variety A grows luxuriantly on potato and acidifies milk slightly. Variety B also grows on potato and digests milk without liquefying gelatine.

II. Types that Produce Acid in Dextrose and Other Sugars.

S. lactis fulvus Conn.

Brownish-red streptococcus. Morphology.—Size .7m.* Gram stain positive. Gelatine colony.—Dense, 5 mm. in diameter, thick, round, white. Acid in litmus gelatine. Gelatine stab.—Needle growth and thin surface growth. Agar streak.—Luxuriant, thick, moist, translucent, reddish-brown. Fermentation tubes.—Acid in all sugar bouillons but no gas or closed arm growth. Bouillon.—Sediment, turbidity but no pellicle. Milk.—Acid and curdled. Potato.—Luxuriant, brown. Grows at 20° and 37°C. Aerobic. Variety A is larger, with negative Gram stain and pellicle on bouillon.

M. lactis aureus Conn.

Yellow, acid cocci, probably non-liquefying forms of S. pyogenes aureus. Morphology.—Size .5-1.2m.* Gram stain positive. Gelatine colony.—Round, thick, smooth, translucent, lemon-yellow. Litmus gelatine acid. Gelatine stab.—Needle growth and yellow surface growth. Agar streak.—Luxuriant, thick, smooth, translucent, yellow. Fermentation tubes.—Acid in all sugar bouillons but no gas, occasional growth in closed arm. Bouillon.—Sediment, turbidity, rarely a pellicle. Milk.—Acidified but usually not curdled. Potato. —Discolored, usually a thick yellow growth. Grows better at 37° than at 20°C. Facultative anaerobic.

S. lactis aureus Conn.

Orange red streptococcus. Morphology.—Size 1-1.2m. Gram stain positive. Gelatine colony.—Round, thick, rough, opaque, creamy white. Gelatine stab. —Needle growth and raised surface growth, orange. Agar streak.—Luxuriant, rough, sometimes dull and wrinkled. Fermentation tubes.—Acid in all sugar solutions but no gas or closed arm growth. Bouillon.—Sediment, turbidity and later a pellicle. Milk.—Slowly acidified and curdled. Potato.—Thick, rough, opaque, yellow. Grows at 20° and 37°C. Aerobic.

S. lactis viscosus Conn.

Morphology.—A streptococcus. Size .8-.9m.* Gram stain positive. Gelatine colony.—Shiny, pale yellow, round or lobate, usually viscous. Gelatine stab.—Needle and surface growth, producing a nail culture. Agar streak.—Lobate, luxuriant, viscous. Fermentation tubes.—Acid in all sugar bouillons and growth in the closed arm but no gas Bouillon.—Sediment, turbidity and pellicle. Milk.—Acidified, curdled and rendered very slimy. Potato.—Luxuriant, dull, pasty growth. Grows at 20° and 37°C. Facultative anaerobe. Variety A shows scanty, non-viscous growth on agar and no pellicle on bouillon.

S. lacticus Kruse.

Morphology.—Long or short chains. Size .5-1m.* Gram stain positive. Gelatine colony.—Minute, white, rough, dense. In litmus gelatine always acid. Gelatine stab.——Moderate needle growth, but no surface. Agar streak.—Barely visible, faint film. Fermentation tubes.—Acid in all sugars, usually growth in closed arm but no gas. Bouillon.—Almost invisible, slight sediment and turbidity. Milk.—Promptly acidified and curdled. Potato.—Usually invisible. This species sometimes comprises 99 per cent of all the bacteria in a sample of milk. The tpye S. lacticus I produces acid in dextrose but not in other sugars. Variety A of this type shows no turbidity but a slight pellicle in bouillon, variety B. turbidity but no pellicle, variety C turbidity and pellicle with negative Gram stain, variety D luxuriant growth on potato. The type S. lacticus II produces acid in lactose and saccharose but not in dextrose. Gram stain negative. S. lacticus III shows pellicle on bouillon and acidifies or curdles milk.

M. lactis acidi.

Morphology.—Micrococcus. Size .5-1.2m.* Gram stain positive. Gelatine colony.—Round, thin, smooth, white, not characteristic. No acid on litmus gelatine. Gelatine stab.—Needle and surface growth. Agar streak.—Moderate, white, smooth or rough. Fermentation tubes.—Acid in all sugars but no gas or closed arm growth. Bouillon.—Sediment and turbidity but no pellicle. Milk.—Sometimes acid sometimes not, usually not curdled. Potato.—Scanty or absent, white. Grows at 20° and 37°C. Aerobic. Constantly found in fresh milk.

M. lactis gigas Conn.

Morphology.—Size 1.5m.* Gram stain positive. No chains. Gelatine colony.—Round, thick, homogeneous, translucent, cream-white. Gelatine stab.—Needle growth but no surface. Agar streak.—Scanty, beaded, translucent white. Fermentation tubes.—Acid in all sugars, no gas or growth in closed arm. Bouillon.—Sediment but no turbidity or pellicle. Milk.—Slightly acidified. Potato.—No growth. Grows at 20° and 37°C. Aerobe or facultative anaerobe.

B. LIQUEFYING COCCI. STREPTOCOCCI AND MICROCOCCI.

I. No Acidity in Sugars.

M. lactis erythrogenes (Grotenfeldt) Conn.

Pink fluorescent coccus. Morphology.—.8m.* No chains. Gelatine colony.—Smooth, flat, reaching .5 mm. in 4 days. Gelatine stab.—Needle growth with slow liquefaction and dense scum. Agar streak.—Luxuriant, white or yellowish, pink fluorescence. Fermentation tubes.—No acid or gas.. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Slightly acidified and digested. Potato.—Luxuriant, yellow, moist. Grows at 20° and 37°C. Aerobic.

M. lactis rubidus Conn.

A red coccus. Morphology.—1m.* No chains. Gelatine colony. Rapidly liquefying, red. Gelatine stab.—Infundibuliform, forming red liquid. Agar streak.—Thick, moist, brick-red. Bouillon.—Pinkish sediment, turbidity, no pellicle. Milk.—No action. Potato.—Luxuriant, blood-red, spreading. Grows at 20° and 37°C., but no pigment at 37°C. Aerobe.

M. lactis citronus Conn.

Orange, liquefying micrococcus. Morphology.—.8-.9m.* Gram stain irregular, no chains. Gelatine colony.—Yellowish, slowly liquefying, with clear liquid. Gelatine stab.—Liquefaction begins in 4 days. Agar streak.—Spreading, thick, smooth, orange. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity and pellicle. Milk.—No action. Potato.—Luxuriant, thick, smooth, orange-brown. Grows at 37°C. Aerobe.

S. lactis citreus I Conn.

Lemon-yellow streptococcus. Morphology.—Size .6-1m.* Gram stain positive. Gelatine colony.—Small, with clear liquid and slow liquefaction. Gelatine stab.—Slow liquefaction, stratiform. Agar streak.—Luxuriant, thin lemon-yellow. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity and pellicle. Milk.—Slight change or digestion. Potato. —Luxuriant, thick lemon-yellow. Grows better at 20° than at 37°. Aerobe. Occasionally varieties of this species fail to liquefy gelatine, or may cause acid in sugars.

S. lactis rogeri Conn.

Lemon-yellow streptococcus. Morphology.—Size .7-1m.* Gram stain irregular. Gelatine colony.—Thin, transparent, granular, slow liquefaction. Litmus gelatine intensely alkaline. Gelatine stab.—Needle growth, stratiform liquefaction. Agar streak.—Luxuriant, thick, lemon-yellow. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment and turbidity.—Milk.—Alkaline, digested, sometimes curdled. Potato.—Luxuriant, yellow. Grows better at 20° than at 37°C. Aerobe.

M. lactis minutissimus.

A minute coccus. Morphology.—Size .2-.3m.* Gram stain negative. Gelatine colony.—Round, thin, smooth in clear pit. Gelatine stab.—Infundibuliform with granular layer, sometimes a dry pit. Agar streak.—Scanty, thin, smooth, yellow. Fermentation tubes.—Acid in lactose, not in other sugars, no gas or closed arm growth. Bouillon.—Sediment, turbidity, no pellicle. Milk.—No change in reaction but curdling and digestion. Potato.—White, dry, wrinkled. Grows better at 20° than at 37°C. Aerobe.

M. lactis aureus A Conn.

Yellowish micrococcus. Morphology.—Size .8-1m.* Gram stain positive. Gelatine colony.—V-shaped in pit with halo. Gelatine stab.—Stratiform with yellow sediment. Liquefaction complete in 14 days. Agar streak.—Luxuriant, brownish-yellow. Fermentation tubes.—No acid or gas. Bouillon.—Pellicle, turbidity, no sediment. Milk.—Rendered alkaline and curdled. Potato.—Luxuriant, brownish-yellow. Grows at 20° and 37°C. Aerobe.

M. lactis albus Conn.

Morphology.—Size .7-1m.* Gram stain positive. No chains. Gelatine colony.—Round, luxuriant, thick, smooth. Gelatine stab.—Slow liquefaction, with dry pit. Agar streak.—Opaque, whitish, moderate, luxuriant. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Slight growth, turbidity, sediment, no pellicle. Milk.—Rendered alkaline and digested. Potato.—Luxuriant, thick, white. Grows at 20° and at 37°C. Aerobe. Six varieties are mentioned showing differences in viscocity, liquefaction, curdling and digestion.

II. Acid in Dextrose or Other Sugars.

M. lactis fluorescens Conn.

Morphology.—Size .5-.6m.* Gram stain negative. Gelatine colony.—Round, moderately thick, smooth, with greenish liquefaction. Gelatine stab.—Stratiform. Agar streak.—Luxuriant, narrow, thick, smooth, white. Fermentation tubes.—Dextrose acid, other sugars alkaline, no gas or growth in closed arm. Bouillon.—Sediment, turbidity, pellicle. Milk.—Acidified, curdled, digested. Potato.—Scanty, thin, smooth, white. Grows at 20° and 37°C. Facultative anaerobe.

M. lactis variens Conn.

Yellow coccus, common in milk.. Morphology.—Size .4-1.4m.* Gram stain positive. Gelatine colony.—Deep and opaque or superficial and white, usually acid in litmus gelatine. Gelatine stab.—Napiform, liquefaction slow or rapid, sometimes a dry pit. Agar streak.—Luxuriant, rough, spreading pale orange. Fermentation tubes. Acid in all sugars, closed arm growth, no gas. Bouillon. —Flocculent sediment, slight turbidity or pellicle. Milk.—Acid, commonly curdled and digested. Potato.—Luxuriant or scanty, pale orange, frequently dry. Grows better at 37° than at 20°C. Facultative anaerobe. Variety A produces acid only in dextrose and does not acidify milk.

M. lactis giganteus Conn.

Morphology.—Size 1.4-3.5m.* Gram stain positive. Gelatine colony.—Cloudy and white liquefying pit. Gelatine stab.—Infundibuliform, liquefaction in 1 day. Agar streak.—Smooth, orange, moderately luxuriant. Fermentation tubes.—Acid in all sugars, no gas or closed arm growth. Bouillon. —Sediment, no turbidity or pellicle. Milk.—Acidified, digested. Potato.—Scanty, beady, brownish. Grows at 20° and 37°C. Aerobe.

M. lactis rugosus Conn.

Perhaps M. acidi lactici Kruger. Morphology.—Size 1-1.2m.* Gram stain irregular. Gelatine colony.—White pit with clear center and granular ring. Gelatine stab.—Slow, crateriform or stratiform. Agar streak.—Luxuriant, viscous, wrinkled, salmon-yellow. Bouillon.—Sediment, turbidity, ring pellicle. Milk.—Acidified, curdled, not digested. Grows at 20° and 37°C. Aerobe.

M. lactis albidus Conn.

Morphology.—Size .6-1.m. Gram stain positive. Gelatine colony.—Opaque, white, not characteristic. Gelatine stab.—Infundibuliform, liquefies in 1-3 days, sometimes dry pit. Agar streak.—Smooth, white, not thick. Fermentation tubes.—Acid in all sugars, no gas, usually no closed arm growth. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Usually acidified and curdled, digestion. Potato.—Moderate, white or yellow. Grows at 20° and 37°C. Facultative anaerobe. There is a variety with white growth on agar, one with more anaerobic character, and one which does not acidify milk.

THE GENUS SARCINA.

Sar. lactis alba Conn.

White or yellow, non-liquefying. Morphology.—Size .7m.* Gram stain positive, no motility. Gelatine colony.—Round, convex, smooth, homogenous, entire. Gelatine stab.—Needle growth, convex surface. Agar streak.—Beaded, raised, smooth, translucent, white moist. Fermentation tubes.—Acid and closed arm growth in all sugars. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Acid, no other change. Potato.—Slight, cream-white. Grows at 20°, very little at 37°C. Facultative anaerobe.

Sar. lactis lutea Conn.

Yellow, liquefying. Morphology.—Size .7-1m.* Gram stain positive, not motile. Gelatine colony.—Slow liquefying pit, nucleus surrounded by granular area. Gelatine stab.—Liquefaction in 3 weeks, crateriform. Agar streak. —Filiform, raised, smooth, opaque, lemon-yellow. Fermentation tubes.—No acid, gas or closed arm growth in any sugar. Bouillon.—Sediment, no turbidity or pellicle. Milk.—Rendered alkaline, slowly digested. Potato—Beaded, raised, opaque, lemon-yellow. Grows at 20° and 37°C. Aerobe.

Sar. lactis aurantiaca Conn.

Orange, liquefying. Morphology.—Size 1m.* Gram stain positive. Not motile. Gelatine colony.—Liquefying pit, orange pigment. Gelatine stab.—Slow liquefaction, stratiform. Agar streak.—Filiform, raised, smooth, moist, orange. Fermentation tubes.—No acid, gas or closed arm growth in any sugar. Bouillon.—Pellicle, slight sediment. Milk.—No change in reaction, curdling, digestion. Potato.—Spreading, capitate, luxuriant. Grows at 20° and 37°C. Aerobe.

Sar. lactis acidi Conn.

Acid yellow. Morphology.—Size .8-1m.* Gram stain positive, not motile. Gelatine colony.—Round, raised, smooth, opaque, brownish. Gelatine stab.—Slow liquefaction or a dry pit. Agar streak.—Filiform, raised, smooth, moist, white or yellow. Fermentation tubes.—Acid in all sugars, no gas or closed arm growth. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Acidified, not curdled or digested. Grows better at 20° than at 37°C. Aerobe.

NON-LIQUEFYING BACTERIA.

I. No Acid in Any Sugar.

B. lactis salmonis Conn.

Salmon-colored. Morphology.—Size .6-1.8m.* Chains. Gram stain positive. No spores or capsules. Gelatine colony.—Round, umbonate, lobed, white. Gelatine stab.—Needle growth, raised surface growth. Agar streak.—Filiform, thin, smooth, white to salmon. Fermentation tubes.—No acid, gas or closed arm growth in any sugar. Bouillon.—Flocculent sediment, membranous pellicle, turbidity. Milk.—Alkaline, no other change. Potato.—Luxuriant, thick, contoured, pink. Grows better at 20° than at 37°C. Aerobe.

B. lactis aureum I.

Orange, non-acid. Morphology.—No chains. Size .7-.9×1-3m.* Capsules, no spores, Gram stain positive. Gelatine colony.—Round, flat, lobed, contoured. Gelatine stab.—Needle growth, thin, reddish surface. Agar streak.—Luxuriant, orange-brown, tough. Fermentation tube.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity, pellicle. Milk.—Orange at surface, no other action. Potato.—Scanty or absent. Grows better at 20° than at 37°C. Aerobe.

B. lactis citreum II Conn.

Yellow, non-acid. Sometimes chains. Size .5-.7×.7-1.4m.* No spores or capsules, Gram stain negative. Gelatine colony.—Round, opaque bead, white turning yellow. Gelatine stab.—Scanty needle growth, dry white surface. Agar streak.—Luxuriant, white to lemon-yellow. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity, flaky scum. Milk.—No action. Potato.—Luxuriant, yellow, thick. Grows at 20° and 37°. Aerobe. In some varieties the lemon-yellow is more pronounced.

B. lactis myceloideum.

Myceloid, no spores. Morphology.—Long filaments .7×2-3.5m.* Gram stain irregular. Gelatine colony.—Myceloid, 2 cm. in diameter, spreading. Gelatine stab.—Needle and surface growth, horizontal threads below surface. Agar streak.—Luxuriant, thick yellowish. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Acid, not curdled. Potato.—Scanty, thin white Grows better at 20° than at 37°C. Aerobe.

B. lactis arborescens I Conn.

Non-acid. Morphology.—Size .9×1.2-1.4m.* No spores or capsules, Gram stain negative Gelatine colony.—Round, raised, smooth, entire, white. Gelatine stab.—Arborescent needle and surface growth. Agar streak.—Scanty, thin, white, slightly viscous. Fermentation tubes. No acid, gas, or closed arm growth. Bouillon.—Sediment, turbidity, ring pellicle. Milk.—Alkaline, slimy, slight digestion. Potato.—Scanty, raised, gray-brown. Grows at 20° and 37°C. Aerobe

B. lactis viscosus Adametz.

Slimy milk bacteria. Morphology.—Size .5-1.2×.5-2.5m.* Filaments 15m* long. Gelatine colony.—Flat, lobate, viscous. Gelatine stab.—Needle growth sometimes granular, thin, shiny, gray surface Agar streak.—Luxuriant, viscous, white. Fermentation tubes.—No acid, gas or closed arm growth. Bouil-

lon.—Sediment, turbidity, pellicle. Milk.—Alkaline, slimy, not curdled. Potato.—Thick, uneven, dirty gray. Grows at 20° and 37°C. Aerobe.

B. lactis acidi var. E.

Very similar to B. lactis acidi. Grows poorly on culture media. Produces no acid in sugars or milk.

B. lactis connii Chester.

Frequent in milk. Morphology.—No spores or capsules. Size .5-.7×1.4m.* Gram stain negative. Gelatine colony.—Round, raised, smooth, white. Gelatine stab.—Needle growth, white surface. Agar streak.—Luxuriant, filiform, raised, smooth, white opaque. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity, ring pellicle. Milk.—Alkaline, not curdled or digested. Potato.—Luxuriant, convex, smooth, white. Grows at 20° and 37°C. Aerobe.

II. Acid in Dextrose or Other Sugars.

B. rudensis connelli.

Red, acid. Morphology. Size 1×1.8m.* No chains or spores. Gram stain positive. Gelatine colony.—Small, below surface, dense. Gelatine stab.—Needle but no surface growth. Agar streak.—Invisible or very thin. Fermentation tubes.—Acid and closed arm growth, no gas. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Acid, curdled. Potato.—Scanty, reddish brown. Grows at 20° and 37°C. Facultative anaerobe.

B. lactis catenansis Conn.

Yellow, spore-bearing. Morphology.—Size .7×1.2m.* Chains. Gram stain negative. Gelatine colony.—Round, raised, homogeneous, transparent, yellow. Gelatine stab.—Needle growth, flat orange surface. Agar streak.—Orange, thin, sometimes wrinkled. Fermentation tubes.—Dextrose and lactose acid, saccharose not. No gas or closed arm growth. Bouillon.—Sediment, turbidity, pellicle. Milk.—Usually no action. Potato.—Luxuriant, wrinkled, orange Grows better at 20° than at 37°C. Aerobe.

B. lactis aureum II Conn.

Orange, acid. Morphology.—Size .8-1.2×1.2-1.8m.* No chains, spores or Gram stain. Gelatine colony.—Round, convex, smooth, entire, orange. Gelatine stab.—Needle and thin surface growth. Agar streak.—Filiform, thin, smooth, moist. Fermentation tubes.—Dextrose acid, lactose and saccharose slightly so. No gas or closed arm growth. Bouillon.—Invisible. Milk.—No curdling or digestion. Potato.—Spreading, thin, smooth, yellow. Grows better at 20° than at 37°C. Aerobe. Aa variety with Gram stain positive.

B. lactis synxanthum.

Morphology.—Size .8-.9×1.2-2m.* Capsule, no spores or chains. Gram stain negative. Gelatine colony.—Round, capitate, smooth, entire, gray. Gelatine stab.—Needle and raised surface growth. Agar streak.—Luxuriant, filiform, raised, smooth, white. Fermentation tubes.—Acid in all sugars. No gas or closed arm growth. Bouillon.—Sediment, turbidity, ring pellicle. Milk.—Acid, not curdled or digested. Potato.—Filiform, raised, contoured, gray. Grows at 20° and 37°C. Aerobe.

B. seifige milch Weig.

Morphology.—Size 1×.5m.* No spores, capsules or Gram stain. Gelatine colony.—Round, capitate, smooth, entire, gray-white. Acid or litmus gelatine. Gelatine stab.—Needle and raised surface growth, becoming dry pit. Agar streak.—Filiform, thin, smooth, gray, moist. Fermentation tubes.—Acid in all sugars, no gas or closed arm growth. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Amphoteric, yellow scum. Potato.—Filiform, thin, smooth, brownish. Grows at 20° and 37°C. Aerobe.

B. lactis isignii Conn.

Digests milk without curdling, does not liquefy gelatin. Morphology.—No chains. Size .5×.3m.* No spores, capsules or Gram stain. Gelatine colony.—Round, raised, smooth, entire, yellow. Gelatine stab.—Filiform needle growth, flat surface. Agar streak.—Luxuriant, filiform, raised, yellowish. Fermentation tubes.—Acid in all sugars after 3 days, no gas or closed arm growth. Bouillon.—Sediment, turbidity, pellicle. Milk.—Acid, digestion. Potato.—Spreading, flat, cream-white. Grows better at 20° than at 37°C. Aerobe.

B. lactis non-acidi Conn.

Morphology.—No spores. Gram stain irregular. Size 1.8×.5-1.2m.* Gelatine colony.—Small, round, thick, entire, white. No acid on litmus gelatine. Gelatine stab.—Needle growth and spreading surface. Agar streak.—Moderate, linear, smooth, moist. Fermentation tubes.—Dextrose acid, sometimes lactose and saccharose. Bouillon.—Sediment, turbidity, sometimes pellicle. Milk.—Alkaline or no change. No digestion. Potato.—Scanty or luxuriant, spreading. Grows better at 20° than at 37°C. Aerobe. Appears almost constantly in milk.

B. lactis ubiquitum.

Morphology.—Long chains, spores, capsule. Size 1.2-1.4×.8m. Gelatine colony.—Round, capitate, entire, white, thin on edge. Gelatine stab.—Needle growth, thick surface. Agar streak.—Luxuriant, white, frost-like growths. Fermentation tubes.—Probably acid, no gas. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Acid, curdling, no digestion. Potato, transparent, spreading. Grows well at 20° and 37°C. Aerobe.

WHITE, ACID BACTERIA.

B. lactis acidi Leichmann.

Immensely numerous. Common cause of sour milk. Several varieties differing from type form. Morphology.—Size .7-1.2×.5-.8m.* Sometimes cocci. Gram stain positive. No motility, spores or long chains. Gelatine colony.—Small points, opaque, not characteristic, mostly below surface. Acid on litmus gelatine. Gelatine stab.—Granular or linear needle growth, no surface. Agar streak.—No growth or barely visible, better on milk agar. Fermentation tubes.—Acid in all sugars, commonly closed arm growth, no gas. Bouillon.—Sometimes no growth, commonly slight sediment. Milk.—Acid, promptly curdled without gas, no digestion. Potato.—Thin, transparent or no growth. Grows better at 20° than at 37°. Facultative anaerobe. Variety A has very minute colony. Milk sometimes curdled in 6 hours. Variety B. has dense surface colony. Variety C is more anaerobic. Variety D never curdles milk.

LIQUEFYING BACTERIA.

I. No Acid in Sugars.

B. lactis chromatum Conn.

Lemon-yellow.—Morphology.—Size 3×1.5m.* Chains and spores, no capsule. Gelatine colony.—Threads in liquefying pit, nucleus with coarse granules. Gelatine stab.—Deep, dry pit, later liquefaction. Agar streak.—Luxuriant, moist yellow. Bouillon. Sediment, turbidity, pellicle. Milk.—Alkaline, curdling, digestion. Potato.—Luxuriant, dry, wrinkled, yellow. Grows at 20° and 37°C. Aerobe.

B. lactis arborescens H.

Morphology.—Rods with square ends. Size 2-4×1-1.8m.* Long chains, spores, no capsule, Gram stain negative. Gelatine colony.—Felted fibers on liquefying disc. Gelatine stab.—Arborescent needle growth, infundibuliform, folded scum. Agar streak.—Spreading, filamentous, cottony. Fermentation tubes. Dextrose and saccharose said to be acid, lactose not. Closed arm

growth, no gas. Bouillon.—Sediment, flaky turbidity, scum. Milk.—Alkaline, curdled, digested. Potato.—Luxuriant, cottony. Grows at 20° and 37°C. Aerobe.

B. lactis filiformis.

Differs from above species in lack of arborescence in gelatine and in slimy growth on potato.

B. lactis truncatum.

Curled colonies. Morphology.—Size 1.2-2.5×.7-1m.* Long chains, spores, no capsules. Gelatine colony.—Opaque, proteus or curled, ¾ inch in diameter. Gelatine stab.—Liquefaction, stratiform, tough, white skin. Agar streak.—Luxuriant, rough, irregular, whitish-yellow. Bouillon.—Felted scum, no turbidity or sediment. Milk.—Alkaline, curdling, digestion, scum. Potato.—Luxuriant, white, velvety. Grows at 20° and 37°C. Aerobe.

B. lactis michiganii Conn .

Morphology.—Size 1.8×.9m.* Chains, spores, Gram stain negative. Gelatine colony.—Rapid liquefaction, cloudy. Gelatine stab.—Liquefaction complete in 3 days, infundibuliform. Agar streak.—Spreading, thick, wrinkled, opaque. Fermentation tubes.—No acid, gas, or closed arm growth. Bouillon.—Sediment, turbidity, wrinkled pellicle. Milk.—Alkaline, curdled, digested. Potato.—Luxuriant, filiform, thick, alveolate, gray-brown. Grows better at 37° than at 20°C. Aerobe.

B. lactis genevum Conn.

Morphology.—Size 3.8×1.4m.* Spores, no chains, Gram stain positive. Gelatine colony.—Smooth liquid mass or cloudy. Gelatine stab.—Needle growth, stratiform, liquefaction. Agar streak.—Spreading, thin, smooth, whitish. Fermentation tubes.—No acid or gas, usually closed arm growth. Bouillon.—Sediment, turbidity, pellicle. Milk.—alkaline, curdled, digested. Potato.—Spreading, smooth, opaque, cream-colored. Grows at 20° and 37°C. Facultative anaerobe.

B. lactis erythrogenes Grotenfelt.

Morphology.—Size 1.2×.9-1m.* Spores, capsule, no chains. Gram stain positive. Gelatine colony.—Round, raised, smooth, entire, translucent, yellowish. Gelatine stab.—Begins to liquefy in 3 days, stratiform. Agar streak.—Filiform, raised, smooth, pink.—Fermentation tubes.—No acid or gas, closed arm growth in dextrose and saccharose not in lactose. Bouillon.—Membranous pellicle, turbidity, flocculent sediment. Milk.—No change in reaction, curdling and digestion in 10 days. Potato.—Luxuriant white. Grows at 20° and 37°C. Facultative anaerobe. Several varieties.

B. lactis rubrum.

Morphology.—Sixe 2-4×.9m.* Chains, no spores or capsules. Gelatine colony.—Bead-form, granular edge, .7 mm. in diameter. Gelatine stab.—Stratiform, clear liquid with scum. Agar streak.—Luxuriant, wrinkled, dull orange or pink.—Bouillon.—Sediment, no pellicle or turbidity. Milk.—Alkaline, curdling after several days, digestion. Potato.—Glistening, smooth, pink. Grows at 20° and 37°C. A variety is orange rather than pink.

B. lactis burri Conn.

Reddish bitter-milk organism. Morphology.—Size 1-3×.7m.* No chains, spores or Gram stain. Gelatine colony.—Surface in liquefying area 1-3 mm. in diameter. Gelatine stab.—Begins to liquefy in 4 days, infundibuliform. Agar streak.—Luxuriant, smooth, lobed, reddish. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Turbidity, no sediment or pellicle. Milk.—Acid, not curdled or digested. Potato.—No. growth. Grows at 20°, not at 37°. Aerobe.

B. lactis citronis Conn.

Lemon-yellow, no spores. Morphology.—Size 1×.6m.* Chains, no capsule. Gelatine colony.—Small pits with nucleus and lighter outer zone. Gelatine

stab.—Crateriform liquefaction with dense sediment. Agar streak.—Luxuriant, thick, folded, greenish-yellow. Bouillon.—Turbidity, sediment. Milk.—Alkaline, digested, sometimes curdled. Potato.—Thick, smooth, pink, or lemon-yellow. Grows at 20° and 37°C. Aerobe.

B. lactis minutissimum.

Slender, orange. Morphology.—Size 1.5×.4m.* Long chains, no spores. Gelatine colony.—Branching on surface, burr-like below, rays into gelatine Gelatine stab.—Begins to liquefy in 2 days, infundibuliform or crateriform, yellow sediment. Agar streak.—Luxuriant, spreading orange. Bouillon.—Sediment, turbidity, pellicle. Milk.—Alkaline, thick, dark-colored. Potato.—Luxuriant, deep orange. Grows better at 20° than at 37°C. Aerobe.

B. lactis marshalli Conn.

Yellow, slimy milk. Morphology.—Size 1.2×.3m.* No chains, spores, capsule nor Gram stain. Gelatine colony.—Slowly liquefying, granular, becoming irregular and slimy. Gelatine stab.—Begins to liquefy in 2 or 3 days, infundibuliform. Not acid. Agar streak.—Luxuriant, viscous, filiform, white or gray. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity, pellicle. Milk.—Alkaline, digested, not curdled. Potato.—Luxuriant, filiform, smooth, lemon-yellow. Grows at 20° and 37°C. Aerobe.

B. lactis limburgii Conn.

Morphology.—Size 1.5-3×.5m.* No chains or spores. Gelatine colony.—Round, brownish, 1 mm. in diameter, after 6 days yellow disc in cloudy liquid. Gelatine stab.—Needle and surface growth, after 6 days liquefaction. Agar streak.—Luxuriant, smooth, glistening, dirty yellow. Fermentation tubes.—No acid, probably no gas. Bouillon.—Turbidity, no pellicle. Milk.—No change in reaction, no curdling, digestion. Potato.—Scanty, yellow, glistening.

B. lactis luteum Zimmermann.

Morphology.—Rod, no chains. Size 1.2×.8m.* No spores or capsule, Gram stain positive. Gelatine colony.—Dense center, clear liquid, slow liquefaction. Gelatine stab.—Slow liquefaction, crateriform. Agar streak.—Luxuriant, filiform, raised, rugose. Fermentation tubes.—No gas acid or closed arm growth. Bouillon.—Sediment, turbidity, membranous pellicle.. Milk—Alkaline, no other change. Potato.—Luxuriant, spreading, thick, opaque. Grows at 20° and 37°C. Aerobe.

B. lactis ashtonii Conn.

Morphology. Size 1.2-3×1.2m.* No chains, spores or capsule. Gram stain irregular. Gelatine colony.—Slow liquefying pit, cloudy, yellowish. Gelatine stab.—Needle growth, napiform liquefaction in 3 days. Agar streak.—Filiform, raised, smooth, yellow, viscous. Fermentation tubes.—Closed arm growth, no acid or gas. Bouillon.—Sediment, turbidity, pellicle. Milk.—Alkaline, curdled, digested. Potato.—Filiform, raised, smooth, yellow. Grows better at 20° than at 37°C. Facultative anaerobe.

B. lactis album Conn.

Morphology.—Rods, no chains. Size 1-3×.7-.9m.* No spores or capsules. Gram stain positive. Gelatine colony.—Slow liquefaction, not characteristic. Gelatine stab.—Liquefaction in 3 days, napiform and stratiform. Agar streak.—Filiform, raised, smooth, opaque, viscous. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity, pellicle. Milk.—Alkaline, curdled, sometimes digested. Potato.—Abundant, spreading convex, brown. Grows well at 20° and 37°C. Aerobe.

II. Acid in Dextrose or Other Sugars.

B. lactis musci.

Morphology.—Long filaments of rods 3×1m. Central spores. Gram stain positive. Gelatine colony.—Myceloid, branching, radiating, white, velvety.

Gelatine stab.—Arborescent needle growth, then wrinkled surface. Agar streak.—Luxuriant, thin, white, wrinkled. Fermentation tubes.—No gas, acid and closed arm variable. Bouillon.—Sediment, turbidity, pellicle. Milk.—Curdling,amphoteric, digestion. Potato.—Luxuriant, thin, whitish. Grows at 20° and 37°C. Aerobe.

B. lactis cretaceum Conn.

Morphology.—Size 3-5×1.4m.* Spores, no chains or capsules. Gram stain positive. Gelatine colony.—Not characteristic, slowly liquefying. Gelatine stab.—No needle growth, liquefaction in 1 day, stratiform. Agar streak.—Filiform, raised, smooth, cretaceous. Fermentation tubes.—Acid and closed arm growth in dextrose and saccharose, no acid or lactose. No gas. Bouillon.—Sediment, slight turbidity and pellicle. Milk.—Alkaline, curdled, digested. Potato.—Spreading, raised, smooth, cretaceous, white. Grows at 20° and 37°C. Facultative anaerobe.

B. lactis lobatum Conn.

Orange, acid liquefier. Morphology.—Size .8-1×.5m.* No chains, spores or capsules. Gram stain positive. Gelatine colony.—Round, raised, smooth, homogenous, sometimes yellowish. Gelatine stab.—Slow liquefaction, saccate then stratiform, liquid cloudy. Agar streak.—Smooth, raised, thin. Fermentation tubes.—Acid in all sugars, closed arm growth, no gas. Bouillon.—Sediment, turbidity, pellicle. Milk.—Acid, not curdled, digested. Potato.—Thick, opaque. Grows well at 20°, poorly at 37°C. Facultative anaerobe.

B. lactis cloacae Conn.

Morphology.—Size .7-.8×.5m.* Capsule, no chains or spores. Gram stain negative. Gelatine colony.—Round, thick, smooth, homogeneous, 1 mm. in diameter. Gelatine stab.—Dry pit, later liquefies, infundibuliform. Agar streak.—Narrow, raised, smooth, opaque. Fermentation tubes.—Acid, gas and closed arm growth in all sugars. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Acid, curdling, no digestion. Potato.—Scanty, white. Grows better at 20° than at 37°C. Aerobe.

B. lactis liquaerogenes Conn.

Morphology.—Size 1-1.6×.7m.* No chains, spores or Gram stain. Gelatine colony.—Rapid liquefaction, not characteristic. Gelatine stab.—Liquefaction from 2nd. to 9th. days. Agar streak.—Moderate, spreading, thin, smooth, white. Fermentation tubes.—Acid, gas and closed arm growth in dextrose and saccharose, no acid or gas in lactose. Bouillon.—Sediment, turbidity, pellicle. Milk.—No change of reaction, curdled, digested. Potato.—Moderate, spreading, thin, white. Grows at 20° and 37°C. Facultative anaerobe.

B. visco-fucatum Harrison and Barlow.

Slimy milk, blue pigment. Morphology.—Size 1-1.8×.6-.9m.* Capsule, no long chains or spores. Gram stain positive. Gelatine colony.—Slimy, yellowish-green crystals. Gelatine stab.—Liquefaction in 10 days, crateriform, inky liquid. Agar streak.—Slow, smooth, viscous. Fermentation tubes.—Probably acid without gas. Bouillon.—Sediment, turbidity, no pellicle, slimy. Milk.—Acid, curdled and digested. Potato.—Luxuriant, yellowish-white, slimy. Grows at 20° and 37°C. Aerobe.

B. lactis brevis Conn.

Morphology.—Size .7-.9×.5-.6m.* No chains, spores or capsules. Gram stain irregular. Gelatine colony.—Round, thin, lobed, whitish. Gelatine stab.—Liquefies in 1 or 2 days, stratiform. Agar streak.—Smooth, white, moderate. Fermentation tubes.—Acid in all sugars, usually closed arm growth, no gas. Bouillon.—Sediment, no turbidity or pellicle. Milk.—Acid, curdled, partly digested. Potato.—Barely visible, thin, white. Grows at 20° and 37°C. Aerobe.

B. lactis fluorescens Conn.

Morphology.—Size 1.4-1.5×.8-.9m.* No chains, spores, capsule or Gram stain. Gelatine colony.—Slow, lace-like, dense center. Gelatine stab.—

Needle growth, stratiform, liquefaction in one day. Agar streak.—Filiform, translucent, smooth, white, green fluorescence. Fermentation tubes.—No gas or closed arm growth, acid in dextrose and saccharose. Bouillon.—Sediment, turbidity, pellicle. Milk.—Alkaline, curdled at 20°C., digestion. Potato.—Filiform, raised, white. Grows at 20°, poorly at 37°C. Aerobe.

B. lactis plicatum Conn.

Non-acid, white, liquefying. Morphology.—Size 3-5×.8-.9m.* Long chains, no spores or capsules. Gram stain irregular. Gelatine colony.—Slow, folding. Gelatine stab.—Needle growth, beginning to liquefy in one day, infundibuliform. Agar streak.—Filiform, thick, smooth, opaque. Fermentation tubes. All sugars slightly acid, no gas or closed arm growth. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Alkaline, curdled, digested. Potato.—Spreading, thick, mottled, wrinkled, white. Grows at 20° and 37°C. Aerobe.

B. lactis gorinii Conn.

Morphology.—Size 1.5-2.5×1m.* Rods with square ends. No chains or spores. Gram stain positive. Gelatine colony.—Slow, large pit, mottled clusters. Gelatine stab.—Begins to liquefy in 2 days, infundibuliform. Agar streak.—Spreading, raised, opaque, white, viscous. Fermentation tubes.—Acid in dextrose and saccharose not in lactose, no gas or closed arm growth. Bouillon.—Sediment, turbidity, pellicle. Milk.—Strongly alkaline, curdled, digested. Potato.—Spreading, thick, opaque, moist. Grows at 20° and 37°C. Aerobe. Three varieties differing in acid relations.

B. lactis magnum Conn.

Morphology.—Size 3×1.5m.* Chains, no spores or capsules. Gram stain positive. Gelatine colony.—Fairly rapid, may be filamentous, ciliated edge. Gelatine stab.—Needle growth, stratiform, liquefaction begins in 1-3 days. Agar streak.—Filiform or spreading thick, punctate, white. Fermentation tubes.—No gas or closed arm growth, acid in dextrose only. Bouillon.—Sediment, turbidity, pellicle. Milk.—Alkaline, curdled, digested into brownish liquid. Potato.—Spreading, thick, contoured, white. Grows at 20° and 37°C. Aerobe.

B. lactis flocculus Conn.

Acid, non-curdling, liquefying. Morphology.—Size 1-2×1m.* No chains or spores. Gram stain positive. Gelatine colony.—Slow, lobate or moruloid. Gelatine stab.—Needle and surface growth. Agar streak.—Filiform, raised, smooth, white. Fermentation tubes.—Acid in dextrose only, no gas or closed arm growth. Bouillon.—Sediment, turbidity, pellicle. Milk.—Acid, not curdled or digested. Potato.—Spreading, thin, contoured, white. Grows better at 20° than at 37°C. Aerobe.

THE GENUS PSEUDOMONAS.

I. Non-Liquefying.

P. lactis middletownii Conn.

Morphology.—Size 1.4×.7-.9m.* No chains, spores, capsules or Gram stain. Gelatine colony.—Round, raised, gyrose, entire. On litmus gelatine coarsely granular. Gelatine stab.—Dry pit, needle growth. Agar streak.—Filiform or spreading, smooth, thin, gray-white. Fermentation tubes.—Closed arm growth and gas in all sugars, no acid. Bouillon.—Sediment, turbidity, pellicle. Milk. Acid, curdled after several days, digested. Potato.—Luxuriant, spreading, thick. Grows at 20°, barely at 37°C. Aerobe or facultative anaerobe.

P. fluorescens aurea Weigmann.

Morphology.—Size 2.5×.9m.* Short chains, no spores, capsules or Gram stain. Gelatine colony.—Round, raised, contoured, grumose, brownish-red. Gelatine stab.—Filiform needle growth, raised surface. Agar streak.—Filiform, smooth, thin, yellowish. Fermentation tubes.—No acid, gas or closed

arm growth. Bouillon.—Red sediment, ring pellicle, turbidity. Milk.—Alkaline or no change in reaction. No other action. Potato.—Filiform, raised, brownish-yellow. Grows at 20° and 37° C. Aerobe. A variety turns gelatine and milk green.

P. lactis estenii, Conn.

Smoky fluorescence, common in milk. Morphology.—Size .8-1.2×.4m.* No chains, spores, capsules, or Gram stain. Gelatine colony.—Round, smooth, capitate, cream-white. Gelatine stab.—Filiform needle growth, raised, dry surface. Agar streak.—Filiform, raised, smooth, translucent, slightly viscous. Fermentation tubes.—No acid, gas, or closed arm growth. Bouillon.—Sediment, turbidity, no pellicle. Milk.—No action. Potato.—Filiform, thin, smooth, gray. Grows at 20° and 37°C. Aerobe.

P. lactis filiformis Conn.

Morphology.—Size 2.5-3.5×.8-.9m.* No capsules, Gram stain negative, spores in long chains, one flagellum. Gelatine colony.—Round, convex, entire, yellowish. Gelatine stab.—Filiform needle growth, flat surface. Agar streak.—Filiform, raised, smooth, yellowish. Fermentation tubes.—No gas or closed arm growth, acid in dextrose and saccharose. Bouillon.—Sediment, ring pellicle. turbidity. Milk.—Acid, no other change. Potato.—Beaded, thick, punctate. Grows better at 20° than at 37°C. Aerobe.

P. pseudotuberculosis Klein.

Morphology.—Size 1.2-1.8×.4-.5m.* Rod. Long chains. Gram stain positive. No spores or capsules. Gelatine colony.—White surface, granular, no gas. Agar streak.—Like B. coli, but less luxuriant. Fermentation tubes.—Probably no acid or gas. Bouillon.—Turbidity, pellicle no sediment. Milk.—No action. Potato.—Thin, crenate, brownish. Found in London milk.

P. lactis viridis Conn.

Morphology.—Size .9-1×.4-.5m.* No capsule, chains or Gram stain. Spores. Gelatine colony.—Round, raised, smooth, entire. yellow. Gelatine stab.—Needle growth with raised surface. Gelatine turned green. Agar streak.—Filiform, raised, translucent, white. Fermentation tubes.—No acid, gas or closed arm growth, except acid in dextrose. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Slightly acid, no other change. Potato.—Filiform, thin, moist, smooth. Grows at 20° and 37°C. Facultative anaerobe.

P. sapolactica Eicholz.

Morphology.—Size .8-1.7×.7-.8m.* No chains, spores, capsules or Gram stain. Gelatine colony.—Round, raised, entire. gray. Gelatine stab.—Filiform needle growth, flat surface. Agar streak.—Filiform, thick, opaque, white. Fermentation tubes.—No acid, gas or closed arm growth, except acid in dextrose. Bouillon.—Sediment, turbidity, ring pellicle. Milk.—Alkaline after a few days, no other change.—Potato.—Slight, linear, thin. Grows better at 37 than at 20°C. Aerobe. Variety A. produces acid in all sugars and curdles milk.

II. LIQUEFYING.

P. lactis anana Conn.

Morphology.—Size .8-1.2×.5m. Chains, no spores, capsules or Gram stain. Gelatine colony.—Rapid, granular pit. Gelatine stab.—Rapid, infundibuliform or stratiform. Agar streak.—Spreading flat, creamish or brown. Fermentation tubes.—No acid or gas, usually no closed arm growth. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Curdled without change in reaction. sometimes greenish. Potato.—Luxuriant, spreading, convex, brown. Grows at 20° and 37°C. Aerobe.

P. lactis eurotas Conn.

Morphology.—Size .9-1.5×.3m.* No chains, spores, capsules or Gram stain. Gelatine colony.—Round, convex, smooth, punctate, entire. Gelatine stab.—

Slow, stratiform. Agar streak.—Luxuriant, linear, flat, gray. Fermentation tubes.—Alkaline, closed arm growth, no gas. Bouillon.—Sediment, turbidity, flocculent pellicle. Milk.—Alkaline, curdled, completely digested. Potato.—Luxuriant, linear, brown. Grows at 20° and 37°C. Facultative anaerobe.

P. lactis nigra Gorini.

Forms black pigment. Morphology.—Size 2-3.5×1m.* No chains, spores, capsules or Gram stain. Gelatine colony.—Slow, pit with irregular center Gelatine stab.—Liquefaction in 12 hours infundibuliform. Agar streak.—Filiform, raised, rugose, opaque. Fermentation tubes.—No acid or gas, slight closed arm growth. Bouillon.—Sediment, turbidity, wrinkled pellicle. Milk.—Acid, curdled, digested. Potato.—Luxuriant, spreading, grayish-brown. Grows at 20° and 37°C. Aerobe.

P. lactis contorta Conn.

Polypiform, monotrich. Morphology.—Size 1-5×.8m.* Spores, single flagellum. Gelatine colony.—Slow, pit at first umbonate. Lobed on litmus gelatine. Gelatine stab.—Filiform needle growth, flat surface becoming dry pit Agar streak.—Moderate, filiform, smooth, opaque. Fermentation tubes.—Closed arm growth, no acid or gas. Bouillon.—Sediment, turbidity, granular pellicle. Milk.—Alkaline, not curdled. Potato.—Luxuriant, filiform, opaque Grows better at 20° than at 37°C. Facultative anaerobe.

P. lactis minuta Conn.

Morphology.—Size .6-.8×.3m.* Very short rod. No chains, spores or capsules. Gram stain positive. Gelatine colony.—Round, smooth, raised, entire, later liquefying. Gelatine stab.—Slow, crateriform. Agar streak.—Luxuriant, filiform, porcelain white Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, slight turbidity, no pellicle. Milk.—Acid, not curdled or digested. Potato.—Invisible. Grows at 20° and 37°C. Aerobe.

P. lactis mina Conn.

Morphology.—Size 1.4-1.8×.6M. Slender rod. No spores, capsules or Gram stain. Gelatine colony.—Slowly liquefying or dry pit, dense at bottom. Gelatine stab.—Deep dry pit, no liquefaction. Agar streak.—Luxuriant, filiform, raised, smooth, white, moist. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Granular sediment, turbidity, membranous pellicle. Milk.—Slightly alkaline, no other change. Potato.—Nodose, contoured, gray, moist. Grows better at 20° than at 37°C. Aerobe.

P. lactis robertii Conn.

Morphology.—Size 2×.7-.9m.* Rods with square ends. No chains, spores or capsules. Gram stain positive. Gelatine colony.—Rapid, greenish-orange pigment. Gelatine stab.—Rapid, stratiform; clear, yellow liquid. Agar streak.—Luxuriant, raised, smooth, moist. Fermentation tubes.—Closed arm growth, no acid or gas. Bouillon.—Sediment, turbidity, membranous pellicle. Milk.—Alkaline, curdled, digested, greenish. Potato.—Moderate, filiform, flat, brown. Grows at 20° and 37°C. Facultative anaerobe.

P. lactis aurea Conn.

Morphology.—Size 1.4×1m.* No chains, spores or capsules. Gram stain positive. Gelatine colony.—Slow, dark-ringed, round. Lobed on litmus gelatine. Gelatine stab.—Filiform needle growth. Flat surface, liquefaction in one day. Agar streak.—Luxuriant, filiform, papillate, lemon yellow. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, slight turbidity, ring pellicle. Milk.—Alkaline, no other change. Potato.—Luxuriant, spreading or beaded. Grows better at 20° than at 37°C. Aerobe.

P. lactis aerogenes A. Conn.

Gas-forming monotrich. Morphology.—Size 1-1.2×.7-.9m.* No chains, spores, capsules or Gram stain. Gelatine colony.—Round, raised or flat, wavy edge. On litmus gelatine large, moist, acid. Gelatine stab.—Very slow, beaded needle growth, thick rough surface. Agar streak.—Thin, whitish, spreading.

Fermentation tubes.—Acid, gas and closed arm growth in all sugars. Bouillon.—Sediment, slight turbidity, pellicle. Milk.—Acid, prompt curdling, slight digestion. Potato.—Scanty, thin, white. Grows better at 20° than at 37°C. Facultative anaerobe.

P. fluorescens Gorini.

Monotrich. Morphology.—Size 1.2-1.8×.7m.* No chains, spores, capsules or Gram stain. Gelatine colony.—Translucent, liquefying, granular, cloudy. Gelatine stab.—Begins to liquefy in 1 day, infundibuliform. Agar streak.—Luxuriant, spreading smooth, opaque. Fermentation tubes.—No gas or closed arm growth. Acid only in dextrose. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Alkaline at 20 C., curdled and digested but not at 37 C., green. Potato.—Luxuriant, spreading, thin, white. Grows better at 20 than at 37 C. Facultative anaerobe.

P. lactis varians Conn

Common in milk. Morphology.—Size 1-1.4×8m.* Chains. No spores, capsules or Gram stain. Gelatine colony.—Round, flat or umbilicate, rugose, brownish. Gelatine stab.—Stratiform or infundibuliform, slow. Agar streak—Filiform, raised, opaque, white. Fermentation tubes.—No gas or closed arm growth, usually acid in dextrose only. Bouillon.—Sediment, turbidity, membranous pellicle. Milk.—Slightly acid and curdled at 20 C, not at 37 C. Potato.—Variable, white to brown. Grows better at 20° than at 37 C. Aerobe. Variety A. liquefies rapidly. **B. acidificans presamigenes casei** Gorini and **P. fragariae** probably belong here.

P. lactis granula Conn.

Morphology.—Spores, chains, no capsules or Gram stain. Gelatine colony.—Rapidly liquefying pit, coarsely granular, ciliated margin. Gelatine stab.—Spiny needle growth, napiform pit, liquefaction in 1 day. Agar streak.—Moderate, raised, filiform, grayish. Fermentation tubes.—Acid in all sugars, no gas or closed arm growth. Bouillon.—Sediment, turbidity, membranous pellicle. Milk.—Slightly alkaline, no other change. Potato.—No growth. Grows well at 37°C, barely at 20°C. Aerobe.

LOPHOTRICHIC BACILLI.

B. syncyanus (Erb) Migula.

Bacillus of blue milk.—Morphology.—Size 1.3-2×.5m.* Short chains, spores, no capsules, Gram stain irregular, polar tuft of flagella. Gelatine colony.—Round, raised, smooth, entire, grayish. Gelatine stab.—Filiform needle growth, thin surface, not spreading. Agar streak.—Luxuriant, spreading, smooth, thin, white. Fermentation tubes.—No gas or closed arm growth, dextrose and saccharose alkaline without change of color, lactose slightly acid and blue-black. Bouillon.—Black sediment, turbidity, membranous pellicle. Milk.—Alkaline, no curdling, blue after a few days. Potato.—Luxuriant, spreading, thick, brownish. Grows at 20° and 37°C. Aerobe.

B. lactis olivaceus Conn.

Morphology.—Size 1.5-2×.4m.* No chains, spores, capsules or Gram stain. Polar tuft of flagella. Gelatine colony.—Round, convex, entire, smooth, reddish. Gelatine stab.—Needle and surface growth, no liquefaction. Agar streak.—Luxuriant, filiform, raised, smooth, greenish. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity, granular pellicle. Milk.—Alkaline, greenish, strong odor, no curdling. Potato.—Luxuriant, filiform, flat, brownish-yellow. Grows at 20° and 37°C. Aerobe.

B. lactis minutus Conn.

Morphology.—Sixe .5×.4m.* Short chains, no spores, capsules or Gram stain. Polar tuft of flagella. Gelatine colony.—Round, convex, smooth, red. Gelatine stab.—Needle growth, no surface. Agar streak.—Filiform, raised, smooth, yellow. Fermentation tubes.—No acid or closed arm growth. Bouil-

lon.—Sediment, turbidity, no pellicle. Milk.—No action. Potato.—Scanty, yellowish. Grows at 20° and 37°C. Aerobe.

B. lactis molecularis Conn.

Morphology.—Size 1.4×.7m.* Flagella at both ends. No spores, capsules or Gram stain. Gelatine colony.—Opaque bead, smooth, entire, white. Microscopic dots on litmus gelatine. Gelatine stab.—Filiform needle growth, flat surface, no liquefaction. Agar streak.—Filiform, flat, smooth, gray-white. Fermentation tubes.—No gas or closed arm growth, acid only in dextrose. Bouillon.—Sediment, turbidity, pellicle. Milk.—Alkaline, curdled, no digestion. Potato.—Scanty, moist, flat, brownish. Grows better at 20° than at 37°C. Aerobe.

B. lactis isignii Conn.

Morphology.—Rod, sometimes chains, spores, capsules, Gram stain positive. One flagellum or a tuft. Gelatine colony.—Rapid liquefaction, not characteristic. Gelatine stab.—Liquefies in 2-12 days, saccate or stratiform. Agar streak.—Spreading, thin, smooth, white, brown at 37°C. Fermentation tubes.—Acid, gas and closed arm growth in all sugars. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Acid, curdled, no digestion. Potato.—Luxuriant, thick, smooth, yellowish. Grows at 20° and 37°C. Aerobe.

II. Liquefying, lophotrichic Bacilli.

B. lactis fluorescens I. Conn.

Morphology.—Size .8-1.6×.4-.6m.* Rod with 2 or 3 polar flagella. No chain, capsules or Gram stain. Spores. Gelatine colony.—Round, gray, smooth, liquefying into granular pit. Gelatine stab.—Rapid liquefaction, infundibuliform, cloudy liquid. Agar streak.—Luxuriant, filiform, raised, gray, moist. Fermentation tubes.—No gas or closed arm growth, acid in dextrose only. Liquid green. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Curdling, digestion, no change in reaction. Potato.—Scanty, filiform, smooth, brownish-yellow. Grows at 20° and 37°C. Aerobe.

B. lactis fluorescens II. Conn.

Lophotrichic rod, sometimes chains. Size 1-1.4×.6-.9. No spores, capsules or Gram stain. Gelatine colony.—Rapid, cloudy pit. Gelatine stab.—Liquefies in 3 days, napiform. Agar streak.—Luxuriant, filiform, smooth, white or brownish. Fermentation tubes.—No gas or closed arm growth, acid in dextrose only. Bouillon.—Sediment, turbidity, flocculent pellicle. Milk.—Alkaline, curdled, digested, green. Potato.—Scanty, flat, brownish. Grows better at 20° than at 37°C. Aerobe or facultative anaerobe.

B. fluorescens minutissimus.

Morphology.—Size .5-.7×.5m.* No chains, spores or capsules. Gelatine colony.—Smooth, liquefying pit, granular. Gelatine stab.—Stratiform, cloudy liquid. Agar streak.—Luxuriant, white, green, fluorescence. Bouillon.—Sediment, turbidity, pellicle. Milk.—Curdled, green at top, no digestion. Potato. —Luxuriant, white to brownish. Grows at 20° and 37°C. Aerobe.

B. lactis fluorescens III. Conn.

Morphology.—Size 1.5-3×.5-.7m.* No chains, spores, capsules or Gram stain. Gelatine colony.—Rapid, granular. Gelatine stab.—Liquefies in 2 days, stratiform. Agar streak.—Luxuriant, spreading, smooth, gray,brown. Fermentation tubes.—Liquid usually green, no gas, acid and closed arm growth in dextrose and sometimes in lactose. Bouillon.—Sediment, turbidity, pellicle. Milk.—Alkaline, curdles, digests. Potato.—Scanty, potato discolored. Grows at 20° and 37°C. Facultative anaerobe.

B. lactis moruloideus Conn.

Morphology.—Size 1-1.5×1.2m.* No chains, spores or capsules. Gram stain irregular. Gelatine colony.—Slow pit, lobed and moruloid. Gelatine stab.—Needle growth, stratiform liquefaction never complete. Agar streak.—

Filiform, raised, smooth, white. Fermentation tubes.—No gas. Sometimes closed arm growth. Acid in dextrose only. Bouillon.—Sediment, turbidity, pellicle. Milk.—Acid, curdled, digested. Potato.—Scanty, thin, smooth, moist. Grows better at 20° than at 37°C. Facultative anaerobe.

PERETRICHIC NON-LIQUEFYING BACILLI.

I. No Acid in Dextrose or Other Sugars.

B. lactis nigroferus Conn.

Black. Morphology.—Size .9-1×.9m.* No spores, chains or Gram stain. Gelatine colony.—Round, thin, smooth, white, later black. Gelatine stab.—Needle and surface growth. Agar streak.—Moderate, smooth, moist, becoming black. Fermentation tubes.—Closed arm growth, no acid or gas, indigo scum. Bouillon.—Sediment, turbidity, black pellicle. Milk.—No change except black scum. Potato.—Thick spreading, moist, blue-black. Grows better at 20° than at 37°C. Aerobe.

B. lactis zenkeri (Hauser) Conn.

Rhizoid or proteus-like. Morphology.—Size 2-3×1m.* Frequently chains, no spores or Gram stain. Gelatine colony.—Rhizoid with lateral extensions. Gelatine stab.—Needle growth, lobate surface. Agar streak.—Thick, white, radiating fibers from ragged edge. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, no pellicle, usually no turbidity. Milk.—Alkaline, no other change. Potato.—Moderately thick, dirty white or brown. Grows better at 37° than at 20°C. Aerobe.

B. lactis colchesterii Conn.

Morphology.—Size 1-2×.7-.9m.* Short chains, capsule, Gram stain positive, no spores. Gelatine colony.—Rhizoid, mold-like. Gelatine stab.—Needle and surface growth. Agar streak.—Mold-like, extending under surface. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity, no pellicle. Milk.—No action. Potato.—Thin, yellow. Grows at 20° and 37°C. Aerobe.

B. lactis nebulus Conn.

Morphology.—Size .8×.3m.* Chains, motile, no spores or Gram stain. Gelatine colony.—Thick, contoured, smooth, yellow. Gelatine stab.—Abundant needle growth, transparent surface. Agar streak.—Luxuriant, thick, smooth, white. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity, pellicle. Milk.—No action. Potato.—Thin, scanty, white. Grows better at 20° than at 37°C. Aerobe.

II. Acid in Dextrose or Other Sugars.

B. lactis citreus Conn.

No chains or spores. Size .8×.5m.* Gelatine colony.—White, opaque, later yellow. Gelatine stab.—Needle growth, lemon-yellow surface. Agar streak.—Luxuriant, lemon-yellow, smooth. Fermentation tubes.—Probably acid without gas. Bouillon.—Sediment, turbidity, pellicle. Milk.—Acid, curdles. Potato.—Luxuriant, white, then lemon-yellow. Grows at 20° and 37°C. Aerobe.

B. lactis rubifaciens Gruber.

Red pigment. Morphology.—Size 2-3×.7m.* Spores, no chains, capsule or Gram stain. Gelatine colony.—Thick, gyrose, white. Gelatine stab.—Needle growth villous, spreading surface. Agar streak.—Linear, moderate, white. Fermentation tubes.—Acid and closed arm growth, no gas. Bouillon.—Sediment, turbidity, ring pellicle. Milk.—Acid, curdled like jelly. Potato.—Thick, white. Grows better at 20° than at 37°C. Facultative anaerobe.

B. lactis sulcatus Conn.

Morphology.—Size 2-2.5×.6m.* Active rod, no chains or spores. Gram stain positive. Gelatine colony.—Large, spreading, white, rough. Gelatine

stab.—Needle growth, thin surface. Agar streak.—Thin, linear, white. Fermentation tubes. Acid and closed arm growth, no gas. Bouillon.—Sediment, no turbidity, or pellicle. Milk.—Acid, not curdled. Potato.—Thin, scanty, moist, white. Grows at 20° and 37°C. Facultative anaerobe. B. aromaticus lactis Grimm may belong here.

B. dysenteriae Shiga.

Suspected but not yet found in milk. Morphology.—Size 1-3m.* in length. Sometimes short. No chains, spores or Gram stain. Gelatine colony.—Nearly same as **B. coli communis.** Gelatine stab.—Needle growth, slight surface. Agar streak.—Luxuriant, uneven, thick, feathery edge. Fermentation tubes.—Acid, no gas. Bouillon.—Sediment turbidity, sometimes pellicle. Milk.—Acid, later alkaline. Potato.—Luxuriant, rough, thick, yellowish. Grows better at 37° than at 20°C. Produces indol. Pathogenic.

B. lactis fragariae (Weig) Conn).

Morphology.—Size 1.3-1.5×.7-.9m.* No chains, spores or gram stain. Gelatine colony.—Round, thick, entire, smooth, white. Gelatine stab.—Needle growth, thin surface. Agar streak.—Scanty, thin, moist, white. Fermentation tubes.—No gas or closed arm growth, acid in dextrose only. Bouillon.—Sediment, turbidity, pellicle. Milk.—Alkaline, transparent. Potato.—Scanty, thin, white. Grows at 20° and 37°C. Aerobe.

PERETRICHIC, LIQUEFYING BACILLI.

I. Producing Pigment.

B. prodigiosus (Ehrb.) Flugge.

Morphology.—Size .5-1×.5m.* Chains, coccoid forms, no spores. Gelatine colony.—Round, oval, entire, reddish-brown. Gelatine stab.—Saccate liquefaction, reddish pigment. Agar streak.—White, later red. Fermentation tubes.—Acid in glucose, gas variable. Bouillon.—Turbidity, red sediment, pellicle. Milk.—Acid, curdled, digested. Potato.—Rose-red, moist, becoming dark red. Grows best at 20°-25°C. Aerobe.

B. butyri rubri Stadling and Poda.

Red spots in butter. Morphology.—Size 1-1.5×.7-.8m.* Chains, no capsule, spores or Gram stain. Gelatine colony.—Round or oval, brown or yellow, central colony in liquid pit. Gelatine stab.—Needle growth, shallow pit. Agar streak.—Luxuriant, opaque, wine-red. Fermentation tubes.—Probably acid and gas. Bouillon.—Sediment, turbidity, no pellicle, rose-red near surface. Milk.—Acid, curdled, cheesy odor, rose-red. Potato.—Luxuriant, carmine. Grows at 20° and 37°C.

B. lactis citronus Conn.

Morphology.—Size 1.5×.8m.* Capsules, no spores or chains. Gram stain positive. Gelatine colony.—Round, convex, smooth, entire, white. Gelatine stab.—Liquefies, infundibuliform. Agar streak.—Filiform, flat, smooth, lemon-yellow. Fermentation tubes.—Closed arm growth, no gas, acid in lactose only. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Acid, curdled, digested. Potato.—Spreading, thin, lemon-yellow. Grows at 20° and 37°C. Facultative anaerobe.

B. lactis harrisonii Conn.

Slimy milk, yellow. Morphology.—Irregular. No chains, spores or capsules. Gram stain positive. Gelatine colony.—Irregular, lobate, slimy, umbonate. Gelatine stab.—Outgrowths from needle track, sinks into pit after 2 weeks. Agar streak.—Luxuriant, viscous, dull. Fermentation tubes.—Apparently no acid or gas. Bouillon.—Turbidity, sediment, ring pellicle. Milk.—Alkaline, not curdled or digested. Potato.—Luxuriant, spreading, intensely yellow. Grows at 20° and 37°C. Aerobe.

B. lactis fluorescens IV Conn.

Morphology.—Size 2.5-3.3×.9-1.5m.* Chains, spores, capsule. Gram stain positive. Gelatine colony.—Granular, central nucleus, liquefying almost immediately. Gelatine stab.—Rapid, infundibuliform. Agar streak.—Filiform, flat, moist, opaque. Fermentation tubes.—Closed arm growth, no gas, acid in dextrose only. Bouillon.—Sediment, turbidity, pellicle. Milk.—Alkaline, curdled, digested. Potato.—Spreading. Grows at 37° and 20° C. Aerobe. Variety A, Gram stain negative, flagella long.

B. lactis niger (Gorini) Conn.

Nearly identical with P. lactis niger Gorini. Morphology.—Size 2-3.5×.9m.* Long chains, no spores or capsules. Gram stain positive. Gelatine colony.—Slow, pit clear then cloudy. Gelatine stab.—Liquefies in 1-10 days, infundibuliform. Agar streak.—Spreading, thin, opaque, white. Fermentation tubes.—Slightly acid, no gas or closed arm growth. Bouillon.—After 3 days sediment, turbidity, pellicle. Milk.—Alkaline, curdled, digested. Potato.—Spreading, irregular, wrinkled, becoming blue-black. Grows better at 37° than at 20° C. Aerobe.

B. lactis arborescens H.

Morphology.—Size 1.5-4×8m. Gelatine colony.—Filamentous, radiating, knotted fibers. Gelatine stab.—Dry pit, later liquefying. Agar streak.—Thin, barely visible, white. Fermentation tubes.—No acid, gas or closed arm growth Bouillon.—Sediment, turbidity, tough scum. Milk.—No action. Potato.—Thin, gray or brown. Grows at 20° and 37°C. Aerobe.

B. lactis rhizoides Conn.

Morphology.—Size 3×.8m.* No chains, spores capsules or Gram stain. Gelatine colony.—Slow, myceloid. Gelatine stab.—Needle growth, saccate liquefaction. Agar streak.—Spreading, thin, white, moist. Fermentation tubes.—. .o acid, gas or closed arm growth. Bouillon.—Slightly sediment and turbidity, no pellicle. Milk.—No action. Potato.—Scanty, white. Grows better at 20° than at 37°C. Facultative anaerobe.

B. lactis mycoides Conn.

Morphology.—Size 1-4×.6-1.2m.* Long chains, spores, no capsule. Gram stain positive. Gelatine colony.—Small, burr-like, rhizoid, rapidly liquefying. Gelatine stab.—Arborescent needle, crateriform. Agar streak.—Luxuriant, dull, wrinkled, tough. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity, pellicle. Milk.—Alkaline, curdled, digested, yellowish. Potato.—Luxuriant, velvety, white. Grows at 20° and 37°C. Aerobe or facultative anaerobe.

B. subtilis.

Very common in milk. Morphology.—Size 1.5-4×.6-1.5m.* Chains, spores, no capsule, Gram stain positive. Gelatine colony.—Rapid liquefaction, irregular granular masses. Gelatine stab.—Liquefies in 1 day. Crateriform, later stratiform. Agar streak.—Filiform, spreading, cretaceous, wrinkled. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity, pellicle. Milk.—Alkaline, curdled, digested. Potato.—Spreading, gray, raised, dry or moist. Grows at 20° and 37°C. Aerobe. Varieties with slow liquefaction and negative Gram stain.

B. lactis cromwelli Conn.

Morphology.—Size 1×.6m. Chains, spores, capsule. Gelatine colony.—Opaque, pit, lobate, then granulat. Gelatine stab.—Dry crateriform pit, later liquefaction. Agar streak.—Luxuriant, white with thin edge. Bouillon.—Sediment, turbidity, pellicle, reddish. Milk.—Alkalin, curdled, digested. Potato.—Moist, slimy, profuse jelly, white or yellowish. Grows at 20° and 37° C. Aerobe.

B. janthinus Zopf.

Morphology.—Size 2-5×.4-5m.* Chains, spores, Gram stain positive. Gelatine colony.—Rapid, membranous surface, sometimes violet. Gelatine stab.—Rapid, cloudy, liquid, pellicle, violet. Agar streak.—Luxuriant, white, then violet. Fermentation tubes.—Probably no gas or acid. Bouillon.—Becoming violet, turbidity, slight pellicle. Milk.—Reaction unchanged or slightly acid. Potato.—Needle track violet, dark brown surface.

II. No pigment or Acid.

B. lactis circulans I. and II.

Morphology.—White circulating bacilli. Chains. Gelatine colony.—Protruding bead in dry pit, then liquefaction. Gelatine stab.—Slow liquefaction, narrow funnel with or without rotating axis. Agar streak.—Luxuriant, thick, yellowish. Bouillon.—Sediment, turbidity, pellicle. Milk.—Alkaline or unchanged, digests with or without curdling. Potato.—Scanty, thin, watery. Grows at 20° and 37°C. Aerobe.

B. aerolactis Conn.

Like B. megatherium Du Bary. Morphology.—Size 1-1.2×.4-.8m.* Spores, no chains or capsule. Gram stain negative. Gelatine colony.—Rapid, cloudy, sometimes nucleus. Gelatine stab.—Liquefaction in 1-10 days, infundibuliform. Agar streak.—Luxuriant, capitate, gray. Fermentation tubes.—No acid. Closed arm growth, gas in dextrose and saccharose. Bouillon.—Sediment, turbidity, ring pellicle. Milk.—Alkaline or unchanged, curdled, digested. Potato.—Spreading, gray, moist. Grows better at 37° than at 20°C. Facultative anaerobe.

B. lactis tetragenes Conn.

Morphology.—Capsule. No chains, spores or Gram stain. Size 3×.7m.* Gelatine colony.—Large, rhizoid or proteus-like, slow. Gelatine stab.—Liquefies in 1-3 days. Stratiform. Agar streak.—Filiform, smooth, gray, moist. Fermentation tubes.—No action. Bouillon.—Turbidity, tenacious pellicle, no sediment. Milk.—Alkaline or unchanged, curdled, slightly digested. Potato.—Luxuriant, thin gray. Grows at 20° and 37°C. Aerobe.

B. lactis distortus Conn.

Morphology.—Size 3×.7m. Chains, no spores or capsules. Gram stain positive. Gelatine colony.—Slow, granular liquid. Gelatine stab.—Slow, stratiform, cloudy liquid. Agar streak.—Filiform, raised, white, moist. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Turbidity, thick scum, no pellicle. Milk.—Amphoteric or no reaction, curdled, digested. Potato.—White, folded, dry or pasty. Grows at 20° and 37°C. Aerobe.

B. lactis gelatinosus Conn.

Produces jelly-like milk. Morphology.—Size .8×.6m.* No chains, spores, capsule or Gram stain. Gelatine colony.—Round, smooth, white, slow. Gelatine stab.—Slow, crateriform, white. Agar streak.—Filiform, raised, smooth, brownish. Fermentation tubes.—No acid, gas or closed arm growth. Bouillon.—Sediment, turbidity, membranous pellicle. Milk.—Acid, curdled, digested into jelly. Potato.—Moderate, raised, brownish. Grows at 20° and 37°C. Aerobe.

B. lactis tenuis (Duel) Conn.

Morphology.—Size 1.2×.5m. No chains, spores or Gram stain. Gelatine colony.—Rapid, not characteristic. Gelatine stab.—Arborescent needle growth, stratiform liquefaction. Agar streak.—Luxuriant, umbonate, gray iridescent. Fermentation tubes.—Closed arm growth. Acid and gas in dextrose only. Bouillon.—Sediment, turbidity, flocculent pellicle. Milk.—Alkaline, digested, curdled. Potato.—Filiform, capitate, gray. Grows at 20° and 37°C. Aerobe. Variety A has Gram stain but no action on milk.

B. lactis plicatus Conn.

Morphology.—Size 2×.8-1.2m.* No chains or capsule. Gram stain positive, central spores. Gelatine colony.—Rapid liquefaction, cloudy pit. Gelatine stab.—Liquefies in 1-10 days, white folded scum. Agar streak.—Nodose, rugose, opaque, white. Fermentation tubes.—No gas or closed arm growth. Acid in dextrose. Bouillon.—Granular sediment, turbidity, pellicle. Milk.—Alkaline, curdled, digested. Potato.—Luxuriant, diffuse, thin, orange-white. Grows better at 37° than at 20°C. Aerobe.

B. lactis amberis Conn.

Morphology.—Capsule. No chains or spores. Gram stain positive. Gelatine colony.—Rapid, not characteristic. Gelatine stab.—Liquefaction in 1-6 days, infundibuliform. Agar streak.—Linear, raised, rugose, yellowish. Fermentation tubes.—No gas. Slight closed arm growth. Dextrose acid, other sugars alkaline. Bouillon.—Sediment, turbidity, no pellicle. Milk.—No reaction, curdled, digested. Potato.—Linear, raised, yellowish. Grows at 20° and 37°C. Facultative anaerobe.

B. mesentericus fuscus Conn.

Morphology.—No chains. Size 1.2-1.5×.4-.6m.* Central spores, Gram stain positive. Gelatine colony.—Round, convex, entire, brownish-red. Gelatine stab.—Slow, napiform. Agar streak.—Spreading, thin, rugose, gray. Fermentation tubes.—No gas or closed arm growth. Acid in dextrose and saccharose. Bouillon.—Slight turbidity, no sediment or pellicle. Milk.—Alkaline, curdled, digested. Potato.—Luxuriant, thin, rugose, brownish-red. Grows better at 37° than at 20°C. Aerobe.

B. lactis vinus Conn.

Morphology.—Size 1-1.2×.6m.* Spores No chains, capsule or Gram stain. Gelatine colony.—Rapid, granular liquid. Gelatine stab.—Needle growth, liquefying in 1-8 days. Agar streak.—Scanty, linear, thin, opalescent. Fermentation tubes.—Acid and closed arm growth, no gas. Bouillon.—Amorphous sediment, turbidity, no pellicle. Milk.—Acid, curdles, digests. Potato.—Scanty, linear, thin. Grows better at 20° than at 37°C. Facultative anaerobe.

B. lactis pruchii Conn.

Slimy milk bacillus. Morphology.—Spores, no capsule or Gram stain. Gelatine colony.—Rapid, not characteristic. Gelatine stab.—Liquefies in one day, stratiform. Agar streak.—Round, flat, opaque, white, viscous. Fermentation tubes.—Acid in dextrose. No gas or closed arm growth. Bouillon.—Viscous sediment, turbidity, pellicle. Milk.—Acid, curdled, digested, yellowish. Potato.—Spreading, thin brownish. Grows at 20° and 37:C. Anaerobe.

B. lactis fungiformis Conn.

Morphology.—Size 3-3.5×1.3m.* No chains. Spores, capsule. Gram stain positive. Gelatine colony.—Mold-like fibers, disappearing after 2 days. Gelatine stab.—Begins to liquefy in 2 days but never complete. Agar streak.—Filiform, grumose, raised, white. Fermentation tubes.—Closed arm growth, no gas, dextrose acid, other sugars alkaline. Bouillon.—Sediment, granular pellicle, no turbidity. Milk.—Alkaline, curdles, digests, strong odor. Potato.—Luxuriant, thick, white, rough. Grows at 20° and 37°C. Facultative anaerobe.

III. No Pigment. Acid in Dextrose and Other Sugars.

B. lactis cloacae Conn.

Morphology.—Size 1-1.3×.7m.* No chains or spores. Capsule, Gram stain positive. Gelatine colony.—Slow, dense granular pit. Gelatine stab.—Liquefaction in 1-6 days, infundibuliform. Agar streak.—Filiform, raised smooth, iridescent. Fermentation tubes.—Acid and closed arm growth. Gas in dextrose and saccharose only. Bouillon.—Sediment, turbidity, pellicle. Milk.—

Acid, curdled, digested. Potato.—Scanty, thin, white. Grows better at 20° than at 37°C. Facultative anaerobe.

B. lactis cloacae A Conn.

Morphology.—Size 1.5×.5-.6m.* Chains. No spores, capsule or Gram stain. Gelatine colony.—Round, raised grumose, wavy edge. Gelatine stab.—Rapid, infundibuliform, much gas. Agar streak.—Filiform, flat, smooth, moist. Fermentation tubes.—Acid, gas and closed arm growth. Bouillon.—Sediment, turbidity, granular pellicle. Milk.—Acid, curdled, not digested. Potato.—Scanty, white. Grows at 20° and 37°C. Facultative anaerobe.

B. (Proteus) vulgaris (Hauser).

Morphology.—Size 1.2-4×.6m.* Long chains. No spores, capsule, or Gram stain. Gelatine colony.—Irregular amoeboid processes. Gelatine stab.—Begins to liquefy in 12 hours, saccate. Agar streak.—Luxuriant, moist, slimy. Fermentation tubes.—Probably gas, and acid in dextrose. Milk.—Acid, curdles, digests. Potato.—Luxuriant, slimy, yellowish-white.

B. lactis diffusus Conn.

Morphology.—Motile. Size 1×.6-.9m.* No chains. Gelatine colony.—Diffuse, faint cloud, mold-like. Gelatine stab.—Napiform, pink liquid. Agar streak.—Luxuriant, pink, moist, smooth. Fermentation tubes.—Probably acid without gas. Bouillon.—Sediment, turbidity, no pellicle, red. Milk.—Acid after several days, curdles, no other change. Potato.—Luxuriant, bright pink. Grows at 20° and 37°C. Aerobe.

B. lactis cochleatus Conn.

Morphology.—Size 1.8-3×.7-.9m.* No chains, spores or capsule. Gram stain positive. Gelatine colony.—Slow, lobed, cochleate. Gelatine stab.—Begins to liquefy in 3 days, stratiform. Agar streak.—Linear or spreading, thin, moist, white. Fermentation tubes.—No gas or closed arm growth. Acid in dextrose and saccharose only. Bouillon.—Sediment, turbidity, no pellicle. Milk.—Alkaline, curdled, digested. Potato.—Very scanty, white.—Grows better at 37° than at 20°C. Aerobe.

B. lactis robertii Conn.

Morphology.—Size 1.5×.5-.8m.* No chains, spores, capsule or Gram stain. Gelatine colony.—Slow, dense, white. Gelatine stab.—Slow, stratiform, cloudy liquid. Agar streak.—Filiform, smooth, white, contoured. Fermentation tubes. Acid in dextrose only, no other change. Bouillon.—Sediment, turbidity, ring pellicle. Milk.—Acid, curdling no digestion. Potato.—Luxuriant, thick, moist, white. Grows better at 20° than at 37°C. Aerobe.

ACID GAS PRODUCERS.

Bacterium aerogenes type.

B. lactis aerogenes Esch.

Morphology.—Size 1.4-5×1-1.5m.* Sometimes capsule. No chains or spores. Gram stain irregular. Gelatine colony.—Thick, round, smooth, moist, sometimes viscous, 2 mm. in diameter. Gelatine stab.—Needle growth, thick, white surface. Agar streak.—Luxuriant, moist, gray. Fermentation tubes.—Acid, gas and closed arm growth in all sugars. Bouillon.—Sediment, turbidity, usually pellicle. Milk.—Strongly acid, curdles, gas. Potato.—Luxuriant, dirty white. Grows better at 37° than at 20°C. Aerobe. No indol. One variety produces indol, a second a thick colony, and two others bitter milk.

The Coli Communis Type.

B. coli aerogenes Conn.

Flagellate. Morphology.—Size 1-3×1-1.4m.* No chains, spores or Gram stain. Gelatine colony.—Prominent, thick, smooth, moist, large. Gelatine stab.—Needle growth, thick white surface. Agar streak.—Filiform, raised,

smooth, opaque. Fermentation tubes.—Acid, gas and closed arm growth, not much gas. Bouillon.—Sediment, turbidity, usually pellicle. Milk.—Strongly acid, curdles with gas. Potato.—Luxuriant, white or straw color. Grows better at 37° than at 20°C. Aerobe. Indol produced, or sometimes not.

B. coli communis Esch.

Like the last species, but produces a thinner, umbonate colony on gelatine with a granular lobate edge. Indol is produced. B. coli is very common in milk on account of the frequent contamination with feces.

B. coli communis.

Typical characters. Morphology.—Size 1-1.6×.4-1m.* No chains, spores, capsule or Gram stain. Flagella peretrichic. Gelatine colony.—Thin, spreading umbonate, smooth center, lobate. Gelatine stab.—Filiform needle growth, spreading, moderate surface. Agar streak.—Filiform, raised, smooth, white, sometimes lobed. Fermentation tubes.—Acid, gas, and closed arm growth in all sugars. Bouillon.—Turbidity, sediment, ring pellicle. Milk.—Acid, curdling, no digestion. Potato.—Moderate, smooth, gray-white. Grows better at 37° than at 20°C. Aerobe. Indol produced. One variety produces gas in dextrose only, and another renders milk slimy.

P. coli communis Conn.

Gas-producing Pseudomonas. Morphology.—Size 1-1.5×.8-.9m.* No spores, chains, capsule or Gram stain. Gelatine colony.—Round, thick, smooth, auriculate, gray. Gelatine stab.—Filiform, umbonate, bluish surface. Agar streak.—Moderate, linear, raised, gray. Fermentation tubes.—Acid, gas and closed arm growth. Bouillon.—Sediment, turbidity, flocculent pellicle. Milk.—Acid, curdling, no digestion. Potato.—Moderate, thin, spreading. Grows better at 20° than at 37°C. Facultative anaerobe. Almost identical with **B. coli communis** except that there is only one flagellum, which is long and characteristic.

In addition to the bacteria which may occur in milk and cause various changes in it a number of fungi other than bacteria may gain entrance to milk. Of these perhaps **Oidium lactis** and **Torula amara** are most common. Brief descriptions of these fungi may be given in this connection.

Oidium lactis.

This is the conidial form of a mildew belonging to the same genus with the powdery mildew of the grape. It occurs normally in sour milk. Morphology.—Fruiting hyphae simple, erect, colorless, bearing at the tips chains of conidia which germinate to form septate hyphae. Takes ordinary aniline stains. The spores or conidia are short cylinders. Gelatine.—Colonies at first white points, becoming stellate and finally covering the entire surface with a mycelial network. Makes similar growth on agar.

Torula amara Harrison.

Morphology.—Oval cells 7.5-10 m.* long, showing vacuolation after a few days, budding at smaller end of cell. Singly or in clumps or chains. No spores. Wort.—Abundant growth at 25°C. No pellicle. Yeast rings form at 37°C. Wort gelatine.—Pin-point colonies becoming round and grayish-white in 4 days. Gelatine stab.—Beaded line becoming dense and spiny. Surface waxy becoming brown at center. Wort agar.—Rapid, luxuriant. Agar.—Glistening, flat. Potato.—In 3 days slightly raised, yellowish growth. Milk.—Bitter in 5 or 6 hours, curdled in 10 days, much gas, no butyric acid.

Extent of Contamination of Milk With Bacteria.

It has already been stated that milk at the moment of its secretion in the normal udder is absolutely free from bacteria. As soon as it reaches the milk cistern at the base of the teats, however, it becomes

contaminated to some extent, usually with bacteria of a comparatively harmless type. In the manipulations to which milk is subjected during milking and in handling until it reaches the consumer and afterward until it is actually consumed it is continually subjected to contamination from outside sources and some of the species of bacteria which were present at the time the milk was drawn are continually multiplying. For these reasons it is obvious that the number of bacteria found in milk will vary enormously according to the age of the sample of milk, the temperature under which it has been kept and the other conditions to which it has been subjected.

When all of the sanitary precautions mentioned in chapter VI are duly considered and put in practice milk may be drawn and bottled or poured into cans in such condition that it contains only a few hundred bacteria per cc. The variation in the number of bacteria actually found in samples of market milk, however, is enormous. Samples of milk which otherwise appear to be in excellent condition may contain 50,000 bacteria per c.c. and in samples of less satisfactory milk the bacterial contamination may vary from this degree up to 200 million or more per c.c. On account of the extremely different conditions which prevail on different dairy farms and in the handling of milk by the different dealers it is obviously of little value to discuss in great detail the extent of bacterial contamination which has been found by actual estimates. A few determinations of this sort may be cited in order to illustrate the great difference in the extent of bacterial contamination. Thus Park in an investigation which he made in a well ventilated and fairly well cleaned barn in which the cows were groomed in a satisfactory manner and in which the milkers were fairly clean but the straining cloths not satisfactorily cared for found the number of bacteria per c.c. in milk cooled to a temperature of 45°F. within two hours after milking was 15,500. After 24 hours the number was 21,000 and after 48 hours 76,000. These figures were obtained in winter. Under similar conditions in summer the number of bacteria per cc. shortly after milking was 30,000, after 24 hours, 48,000 and after 48 hours 680,000. In the case just cited the necessity of sanitary precaution in handling milk was fairly well understood. The bacterial contamination, however, in cases where no attempt is made to prevent the entrance of bacteria into milk is enormously greater. Thus according to examinations of milk in St. Petersburg the number of bacteria per c.c. in farm milk was 9,800,000, in creamery milk 1,150,000,000 and in milk delivered to ordinary customers along the milk route 82,000,000. Similar figures obtained for milk furnished to various other European cities show a contamination ranging from 4,000,000 to 170,000,000 bacteria per c.c.

In tests made by Loveland in Middletown, Conn., the number of bacteria per c.c. in samples of milk ranged from 11,000 to 300,000. In a similar examination made by Russell in Madison, Wis., the number ranged from 35,000 to 2,000,000. In a number of samples

of market milk taken in Washington, Boston and New York, bacterial contamination has been found as high as 2,500,000 to 600,000,000 per c.c. When these enormous figures are compared with those obtained from an examination of milk drawn with special precautions by commercial dairymen who appreciate the necessity of sanitation in regard to milk, it is apparent that too much importance cannot be laid upon the strict observance of the simple rules which have been shown to be effective in preventing the bacterial contamination of milk. It has been demonstrated, for example, in numerous instances in large dairies furnishing milk to the chief cities of the United States, that the number of bacteria per c.c. need not exceed 500 to 1,000 at the time the milk is delivered to the consumer. Nevertheless boards of health have in no instance insisted upon such a low bacterial content in formulating a milk standard. It has been necessary to allow a greater bacterial contamination for the practical reason that at present not enough dairymen are properly equipped to furnish the necessary amount of milk with a bacterial content not exceeding 1,000 per c.c. In practice it has been found that milk containing not more than 10,000 to 50,000 bacteria per c.c. of the ordinary species is a satisfactory milk for ordinary use. Milk intended for children should contain fewer bacteria and such milk can be obtained in all of our large cities.

Influence of Temperature Upon the Bacterial Content of Milk.

It is well understood in general that cold aids in preserving milk for the simple reason that it checks the development of those bacteria which produce souring and other changes in the milk. Since it is practically impossible to obtain milk absolutely free from bacteria it is therefore necessary that cold should be applied to milk at once in order to prevent the multiplication of bacteria. The keeping of milk is everywhere closely dependent upon temperature. At high temperature milk sours and undergoes other changes rapidly. At moderate temperatures these changes take place less rapidly, while at a temperature of 40 degrees F. the souring and other changes may be postponed for a long time. If milk is actually frozen it may be kept indefinitely without any appreciable change.

Conn, Freudenreich and numerous other investigators have carefully studied the influence of temperature upon the keeping property of milk. In one experiment reported by Conn a sample of milk was divided into two parts, one of which was maintained at a temperature of 50° and the other at 70° F. The number of bacteria per c.c at the beginning of the experiment was 16,000. After twelve hours the number in the milk kept at 50 degrees F. was 39,000, and in that kept at 70°, 249,000. After fifty hours the number of bacteria per c.c. in the milk kept at 50 degrees F. was 1,500,000 and in that kept at 70°, 542,000,000.

In further tests along this line it was found that in a period of twenty-four hours the bacteria ordinarily present in milk will multiply only five-fold at a temperature of 50° F, but 750-fold at a temperature of 70° F. Similarly it was found that milk kept at 95° F. will curdle in about 18 hours, at 70° F. in 48 hours and at 50° F. not until after two weeks or more in many of the samples.

It might be concluded therefore as indicated by Conn that the keeping quality of milk is more a matter of temperature than of cleanliness. In fact milk may be almost indefinitely prevented from souring or showing other visible changes merely by the application of cold. Nevertheless milk gradually becomes filled with bacteria of a more harmful nature than the lactic acid organisms and other bacteria which grow at higher temperatures. For this reason, milk kept for long periods by means of cold is unfit for use although it may be perfectly sweet.

The application of cold in the preservation of milk may in one respect be considered from the same standpoint as the use of preservatives. The low temperatures serve to prevent the development of the bacteria which are already present in the milk and thus mask to the consumer the extent of contamination of the milk. In the case of badly contaminated milk, therefore, the application of cold may simply make it possible to sell milk which would otherwise quickly show such visible changes as to render its sale impossible. Nevertheless refrigeration must be used in the handling of milk for the reason that otherwise all milk would sour too soon for practical purposes and the high temperature of the air, particularly in summer, would permit of the rapid multiplication of the less harmful bacteria, which, however, would cause souring and other undesirable changes.

The Time Factor in the Number of Bacteria in Milk.

At the temperature of an ordinary living room common milk bacteria will divide every twenty to thirty minutes. By means of a simple calculation it is easy to demonstrate that the presence of a few hundred bacteria per c.c. in milk at the time it was drawn will lead in the course of twenty-four hours, if low temperatures are not maintained, to an enormously high number of microorganisms. In investigations carried on by Freudenreich it was found that the number of bacteria multiplied from 500,000 to 85,000,000 per cu. in. in the course of twenty-four hours. Other examples of equally rapid multiplication are cited by the same investigator in which the number increased steadily from the outstart of the observations. The rapidity of multiplication depends in large degree upon the cleanliness which is observed in the milking and handling of milk. Any pollution added to the milk after it is drawn will obviously tend to increase greatly the number of bacteria. Thus in observations made by Park in New York upon milk kept at a temperature of 90° F., the number of bacteria per c.c. in good, fresh milk, fair store milk and poor store milk

was 5,000, 92,000 and 2,600,000 at the outset and 654,000, 6,800,000 and 124,000,000 respectively after eight hours. As already indicated the rapidity of multiplication is greatly diminished by keeping the milk at a low temperature. The intervals between the divisions of the micro-organisms are greatly lengthened and some of the species are not able to multiply at all on account of the predominance and antagonistic influence of other species.

Antagonism Between Bacteria of Different Species.

Attention has already been called to the fact that when a considerable number of species of bacteria is present in milk not all of them are able to multiply at the same rate. Most species of bacteria thrive best on a neutral or slightly alkaline medium. In nearly all milk, however, as it comes from the udder, there are a number of lactic acid bacteria which soon produce sufficient acidity in the milk to check the growth of a number of species of bacteria which do not thrive in the presence of acid. Other kinds of antagonism have been noted in mixed culture experiments in which several species of bacteria are grown in the same medium. In some cases one organism appears to produce substances as a result of growth which actually favor the growth of other bacteria, while in other cases the changes produced in a medium by one species of micro-organism and the toxins or other bodies thereby produced antagonize or entirely prevent the growth of certain other species of bacteria. The multiplication of bacteria in milk, therefore, is never as rapid as would be possible if no unfavorable conditions were present.

Means of Reducing the Number of Bacteria in Milk.

In chapter VI attention has been called to those practices in dairying which have been found to reduce the number of bacteria as found in milk at the time it is delivered to the consumer. It is unnecessary, therefore to discuss in detail these means of the bacterial sanitation of milk in this connection. The most essential thing is to exercise such cleanliness in milking and handling milk as will prevent the contamination of milk. By the exercise of common sense and intelligence, enlightened by modern bacteriological studies of milk it is possible to obtain milk with a very slight bacterial contamination and to handle and deliver it in such a way that no subsequent contamination takes place, and the multiplication of bacteria which were originally present is reduced to a minimum. It has been repeatedly stated, however, that aseptic milk on a commercial scale is a practical impossibility. Some bacteria are always present in the milk as it comes from the udder. The dairyman must therefore apply cold at the start in order to prevent too rapid multiplication of these organisms. The observance of cleanliness, therefore, and the application of cold to milk until the time of its delivery are the chief means upon which the dairyman must depend in furnishing pure milk to his patrons.

Growth of Bacteria in Milk.

It has already been indicated that the majority of bacteria require for their rapid growth the presence of certain organic compounds in a readily available form. These compounds are found in milk in an almost ideal condition at the time when it is drawn from the udder. The casein and other albuminous constituents of milk furnish a sufficient quantity of protein for the growth of bacteria. Lactose or sugar of milk is perhaps the form of sugar which is most readily available for the use of bacteria and most easily decomposed and otherwise influenced by them. The presence of fat in a low percentage is favorable to the growth of many species and this constituent likewise is present in fresh milk in the form of butter fat. Moreover milk at the time it is drawn has a neutral or at least only slightly acid reaction and in this respect it is therefore a suitable medium for the growth of bacteria. These conditions originally present in milk as it is drawn from the udder are rapidly changed by the growth of the bacteria in it. The reaction of milk soon becomes acid as the growth and multiplication of lactic acid bacilli proceed and the percentage of acid in the milk soon reaches a point where many of the gas-forming and liquifying bacteria are no longer able to grow. On the other hand the lactic acid bacteria are very susceptible to the influence of heat and are therefore readily killed by the pasteurization of milk. In pasteurized milk, therefore, souring does not take place readily and favorable conditions are presented for the growth of such gas-forming and putrefactive bacteria as may be present in the milk. These highly undesirable changes in pasteurized milk can only be prevented by the application of cold.

Souring of Milk.

The familiar phenomenon of the souring of milk is one of the results of the presence of bacteria in the milk. The souring of milk is so well known and takes place after the lapse of a certain time with such unfailing regularity that the process is often considered as a natural phenomenon in connection with milk. Nevertheless it has been repeatedly shown that milk free from bacteria may be kept in hermetically sealed vessels for months without souring and without showing any other visible change. The souring of milk is therefore due to the presence of a foreign body in it and has been definitely connected with the growth and multiplication of lactic acid bacteria which produce the ferment necessary to cause the change from the neutral to the acid reaction. In the process of souring, milk curdles or becomes semisolid and the percentage of acid gradually increases. The lactic acid arises from the prompt decomposition of the milk sugar by the action of bacteria. The lactic acid bacteria are undesirable in milk, at least in large numbers, if the milk is intended for delivery to the regular customers of a milk route for consumption as such. In the manufacture of butter and cheese, however, these organisms are of the greatest

utility and are depended upon for the ripening of cream and cheese and the production of certain flavors and other changes which are expected in butter and cheese. The utilization of lactic acid bacteria in the manufacture of butter and cheese, however, is a matter which belongs to technical dairying and cannot be further discussed in this connection.

Coagulation of milk is perhaps more properly used to refer to a process quite different from that of ordinary curdling. Curdling, as we have used it in this connection, denotes the change from a fluid to a semi-solid condition in milk as the result of the growth of lactic acid bacteria. This is one form of fermentation, but coagulation proper is a condtion which is brought about in milk during the manufacture of cheese and is due to a coagulation fermentation in which the curd differs in composition and in physical structure from the curdled semi-solid mass in milk soured simply by the action of lactic acid bacteria. The coagulation of milk may be brought about by the use of rennet. This ferment is commonly used, as is well known, in the coagulation of milk in the manufacture of cheese. Rennet contains a specfic ferment known as rennin and is chiefly obtained from the mucous membrane of the fourth or true digestive stomach of calves. It is also present in the pancreas of man and a number of other animals.

Conn and others have shown that certain bacteria may produce during their growth a ferment which shows all of the essential characteristics of rennet. These bacteria may possess at the same time a ferment which digests the milk. In some instances only one of the ferments is present. Coagulation may be brought about first, after which digestion takes place, or the digestion of milk may occur without previous coagulation. Duclaux and others isolated a ferment to which the name "casease" was given, which is produced by bacteria and which brings about the digestion of the casein in milk after it has been coagulated by the action of the enzyme producing bacteria.

The bacteria which produce the rennet-ferment and casease are the most important forms of enzyme-producing bacteria found in milk. Casease as present in milk causes the digestion of the casein already formed by the rennet enzyme and in its action and composition so far as it has been determined differs very little from pepsin and trypsin. The enzyme-producing bacteria are not so common in milk as many other forms and when present may coagulate milk rapidly without the formation of acid. They are thus readily distinguished from the lactic acid bacteria which develop a considerable percentage of acid in connection with the curdling of milk. If the liquifying or digesting bacteria are present in milk the milk must be looked upon with some suspicion. Bacteria which digest casein also liquify gelatine and their presence is therefore readily detected by the use of gelatine cultures.

Swithinbank calls attention to the fact that milk may occasionally coagulate spontaneously. This was first demonstrated by Levy, who

showed that a slight coagulation may be observed in nearly all sterile samples of milk which are allowed to stand for a long time. The casein of the milk however is not all coagulated. In fact in most such samples of milk only small fragments of the casein are coagulated.

Abnormal Fermentations.

As contrasted with the kinds of fermentation already described as occurring in milk there are a number of others which produce striking changes in the color or appearance of the milk and are universally referred to as abnormal fermentations. The essential physical features of these fermentations have been referred to in chapter II on abnormal milk and are mentioned here merly from the standpoint of bacteriology. Red milk as distinguished from bloody milk is due to the presence of *micrococcus prodigiosus*. This organism grows quite rapidly upon the surface of milk, causing red spots. The milk serum is not affected. One or more other organisms have also been described as causing a red color in milk.

Yellow milk is due to the action of a number of bacteria which produce a yellow pigment, particularly the *Bacillus synxanthus* of Adametz. These bacteria act quite differently upon milk, some of them causing a pronounced yellow color rapidly, while others appear to produce a coagulation of the milk, after which the yellow color appears.

Blue milk was formerly mentioned quite frequently as a pathological condition observed in the examination of milk. It was referred by Hüppe to the action of *Bacillus cyanogenes*. Milk affected with this bacillus does not differ in other respects from ordinary milk. After a varying length of time, however, small blue spots appear on the surface of the milk and these spots may coalesce to form a complete covering to the sample of milk.

Slimy or ropy milk is sometimes observed, usually as the result of insufficient cleansing of milk utensils. The peculiar fermentation of milk resulting in the production of slimy threads is commonly due to the action of certain micrococci and bacilli, a number of which have been mentioned by different investigators. These include at least twelve species mentioned by Adametz, Guillebeau, Schmidt, Conn and others and are described in the list of milk bacteria given above. The condition known as slimy milk is commonly caused by *Bacillus lactis viscosus* but may also be due to a micrococcus in certain instances.

Occasionally milk shows a bitter flavor which is not due to the consumption by the cows of bitter weeds but to micro-organisms which gain entrance to the milk. The bitter flavor is caused by certain micrococci or bacteria, the chief organisms being different in different cases. In one instance cited by Conn the bitter flavor was produced by bacteria which were present in the udder of one cow in a herd and disappeared as soon as this cow's milk was excluded.

An organism was isolated by Weigmann from milk which frothed, had a soapy feeling and flavor and appeared to be otherwise abnormal. The organism in question is described in the list of milk bacteria above.

Various other abnormal conditions of milk not due to bacteria are described in more detail in Chapter II.

The Significance of Streptococci in Milk.

In the sanitary crusade which has been carried on in recent years for a pure milk supply for large cities, it has usually been considered by health officers and others interested in this problem that the presence of streptococci in milk indicate a pathological condition of the udder of the cow. The ordinary streptococci found in milk have been generally supposed to be associated with the presence of pus cells in milk and have therefore been held as a sufficient ground for casting serious suspicion upon the condition of the milk in which they are found.

Recent investigations regarding the kind and number of bacteria found in the milk ducts and teat canals show that these micro-organisms may be readily divided into two groups, one producing lactic acid fermentation and containing the two common types of bacillus lactis acidi and bacillus lactis aerogenes and the other producing no acid but causing the appearance of various odors and flavors or putrefactive changes in the milk. The common lactic acid organisms, however, have been shown by Hölling, Kruse, Heinemann and Harris to exist under a variety of forms, particularly that of the bacillus and also of the streptococcus. These investigators have cast considerable doubt upon the importance previously attributed to the presence of streptococci in milk. It is certain that pathogenic streptococci may be found in milk at times, particularly in cases of contagious mammitis or garget. In cases where these organisms are to be recognized in the milk, however, the disease can also be diagnosed by an examination of the cow. Harris and others call attention to the fact that bacteriological methods do not differentiate with certainty between pathogenic and non-pathogenic streptococci. The investigators just mentioned are all decidedly of the opinion that the common lactic acid bacteria may exist under the form of streptococci and that therefore the presence of streptococci in milk may not indicate any abnormal contamination. The whole question of the significance of streptococci in milk is therefore thrown open for further investigation.

Comparative Growth of Different Species of Bacteria in Milk.

The subject of the relative rate of growth of different species of bacteria in milk and the suitability of milk as a medium for the growth of these different kinds of bacteria has been referred to above. A number of investigators have made a study of this point. By adding litmus

and milk sugar to the ordinary gelatine medium Conn was able to identify about thirty species of bacteria which were mostly found in milk a few hours old. This method suffers somewhat from the fact that the gelatine plates have to be kept three to five days or longer and when liquefying bacteria are present a complete liquefaction of the gelatine takes place before the colonies of the bacteria can be identified. Among the most common species found in comparatively fresh milk were two forms of bacillus lactis acidi, bacillus lactis aerogenes, several species of streptococcus, bacteria producing rapid or slow liquefaction and two species of sarcina. In samples taken after the milk had been allowed to stand for eighteen hours or more bacillus lactis acidi was found to have increased with marvellous rapidity, sometimes constituting 99% of the total number of bacteria. The other species decreased both relatively and absolutely and the liquefying bacteria often disappeared entirely.

In 272 samples of milk studied by Bergey immediately after the milk had been drawn three types of micro-organisms were most frequently observed, viz: streptococcus, staphylococcus and a bacillus of the pseudo-diphtheria type. The streptococci were present in largest numbers sometimes to the extent of 5,000 per c.c. In milk examined by the same investigator after it had been allowed to stand for some time and had been subjected to the possibility of infection from the air, milk vessels, and other sources, another set of micro-organisms was found to have been added. This included chiefly putrefactive bacteria which produced an alkaline reaction in milk cultures and liquefied gelatine. Many of these organisms were such as are commonly found in water and probably gained entrance to the milk through the water used in washing milk vessels. Attention is called to the fact that these organisms are not pathogenic but they belong to a group which produces putrefaction in milk with the possible formation of poisonous ptomaines.

Methods of Bacteriological Examination of Milk.

It is impossible within the limits of the present volume to describe in detail the methods of preparation of the numerous culture media which have been used by bacteriologists in the study of bacteria in milk and of the great variety of stains which have been employed to assist in the identification of bacterial species. It is assumed that the milk inspector who makes bacteriological examinations of milk is familiar with the technique of these matters and in this connection only such points will be discussed as have immediate bearing upon the application of the bacteriology to the study of milk. In the bibliographical list titles will be found of original articles and other sources in which information can be found regarding the preparation of culture media and stains and the use of bacteriological apparatus.

Culture media.—In the extensive and long continued investigations which Conn and his associates have made upon milk bacteria the isola-

tion of the various species of milk bacteria has been for the most part accomplished by the use of litmus gelatine. In Conn's experience this medium has given a better differentiation of colonies than any other solid media commonly used for the purpose. As soon as bacterial cultures have been thus isolated and purified they are re-inoculated upon agar streaks and after about two days' growth on this medium are again inoculated into various other culture media at the disposal of the bacteriologist. Conn has found it desirable to use fresh cultures on agar streaks to determine the morphology, using older cultures if necessary to study the formation of spores. The motility of bacteria is ordinarily studied by Conn in a hanging drop of bouillon culture of twelve to twenty-four hours' growth. The flagella are commonly studied by the same investigator by removing a portion of the hanging drop with a platinum loop and spreading it over the surface of solidified agar which is then incubated for twelve hours at a temperature of 37 degrees C., after which a small quantity is removed and stained by the Loeffler method.

In Conn's study of milk bacteria preference is expressed for the use of Liebig's beef extract in the place of chopped beef in the preparation of bouillon, gelatine and agar. Tests in fermentation tubes are made with dextrose, lactose and saccharose, one per cent of these sugars being added to ordinary bouillon. The milk which Conn uses for cultures is skimmed and sterilized by boiling for ten to fifteen minutes on three successive days. Potato cultures are made by cutting plugs from large potatoes, slicing them obliquely, soaking them over night in running water and sterilizing them in tubes in an autoclave. The peptone-agar culture recommended by Conn is prepared by using 10 grams of dry peptone, 5 grams common salt, 5 grams Liebig's beef extract and 30 grams of milk sugar in 500 liters of water. Conn's sugar gelatine contains 13 grams of peptone, 150 grams gelatine, 7 grams Lieibg's beef extract and 30 grams of milk sugar in a thousand c.c. of water.

Quantative examination of milk.—The technique of the bacteriological examination of milk is discussed in unusual detail in the excellent volume by Swithinbank and Newman on the Bacteriology of Milk. Some of the methods which these investigators have found to be of greatest practical value are briefly summarized in the following paragraphs:

The apparatus required for the bacteriological study of milk include ordinary pipettes, dropping pipettes accurately calibrated, an abundant supply of test tubes, conical flasks marked at a point indicating 49 cc. and Petri dishes. In making a dilution of milk taken from a sample selected for examination, the procedure as described by Swithinbank and others is comparatively simple. Using a sterilized pipette one c.c of the milk is added to a test tube containing 9 c.c. of sterile water. The milk and water are thoroughly mixed and this constitutes the primary dilution in the proportion of 1 to 10. If one cc. of the

primary dilution be added to a flask containing 49 cc. of sterile water the total content will obviously be 50 cc., containing one-tenth of the original quantity of milk, or in a dilution of 1 to 500. If a dilution of 1 to 1000 is desired it is easily obtained by transferring one cc. of the primory dilution to a second tube containing 9 cc. of water and again one cc. of this mixture to a third tube. Whatever the extent of final dilution which is adopted it will be found desirable in estimating the bacteria of milk to inoculate three Petri dishes from each sample, using 1 drop, 2 drops and 4 drops respectively. If the sample of milk contains a relatively small number of bacteria, it may be desirable to use ten drops for inoculation.

The transfer from the final dilution to the Petri dish may be made as follows: aspirate a small quantity of liquid from the final dilution into a calibrated dropping pipette, add the desired quantity of the diluted milk to the tubes of gelatine being careful to prevent any other bacterial contamination, roll the gelatine tubes in the hand until the diluted milk is thoroughly mixed with the gelatine, then pour the gelatine into the Petri dish carefully, so as to obtain a level surface and keep the dish level until solidification takes place. For ordinary milk bacteria the temperature of the living room is the best at which to maintain the Petri dishes of gelatine during the incubation of the bacteria. The colonies of bacteria on the gelatine in the Petri dishes are to be counted on the second, third and fourth days and these counts should include not only the total number of colonies but also the number of colonies which produce liquefaction of gelatine. After the number of bacteria in the minute quantity of diluted milk placed in the Petri dish has been determined by an examination of the culture a simple mathematical calculation will give the number of bacteria per c.c. of the milk. Thus if one drop of a dilution at the rate of 1 in 500 be taken and 75 organisms are found on the plate, the number of bacteria per c.c. of this milk is 750,000, for one drop equals .05 or 1-20 cc. and $75 \times 20 \times 500 = 750,000$.

For staining milk bacteria the stains usually recommended include carbolfuchsin, methylene-blue, Loeffler's alkaline blue and gentian-violet. For compound staining and for special purposes it is of course necessary to use the Gram method, particularly as modified by Nicolle, the Ziehl-Neelsen method, Pitfield's method or McCorie's method for staining flagella, Moeller's method for staining spores and MacConkey's for staining capsules.

Choice of culture media.—The standard liquid media for cultivation of milk bacteria are bouillon and milk, and the standard solid media gelatine and agar, the latter being necessary for use in the cultivation of organisms requiring a blood heat. Gelatine may in fact be considered as a solid bouillon and gelatinized milk may be prepared as a solid form of milk media. The cultures uniformly used by Conn in the study of all milk bacteria include gelatine colony, gelatine stab, agar streak, fermentation tubes, bouillon, milk and

potato. These are sufficient for all ordinary milk bacteria and no addition will be necessary to this list of cultures except in the case of special bacteria for which special culture methods are required. Thus glycerine and potato are commonly used for the tubercle bacillus and carbolized media for the typhoid bacillus. Bacteria which produce cholera nearly always grow well on potato. The variety of media which have been used for the cultivation of bacteria is almost unlimited, but the standard culture media are all that the milk inspector will have occasion to use for practical purposes.

Qualitative examination of milk.—In making a rapid differentiation between the various groups of bacteria which may be found in milk it is necessary to transfer minute quantities of each sample of milk to several kinds of nutrient media. Thus the aerobic organisms may be separated by using simultaneously gelatine, agar and blood serum. The growth of bacteria upon these culture media should enable the milk inspector to detect the presence of ordinary milk bacteria as well as the bacillus of diphtheria, tuberculosis, pseudo-tuberculosis, dysentery, coli bacillus and streptococci. The cultivation of anaerobic bacteria require special apparatus since they must be grown in a vacuum or in hydrogen. For this purpose various tubes have been devised by Vignal, Roux, Esmarck, Fraenkel, Pasteur and others.

Bacteriological examination of air.—The milk inspector may find it desirable to determine the extent of bacterial contamination of the air of stables in forming a general opinion as to the sanitary condition of the premises. For this purpose perhaps the best results are obtained by exposing plates of nutrient agar or gelatine for a short time in different parts of the stable according to the method proposed by Koch. Several other methods have been proposed in which measured quantities of air are drawn into air tubes for the purpose of sampling to determine the bacterial content.

Bacterial examination of water.—If any suspicion is entertained regarding the quality of the water supply used for watering stock or washing the milk utensils, chemical tests may be applied such as are used in detecting various foreign bodies in milk, as discussed in chapter XI. Bacteriological examinations may be made in essentially the same manner as the inspector would proceed in the quantative examination of milk. In most instances satisfactory results will be obtained if five gelatine plates are inoculated with quantities of the water to be examined ranging from .1 to .5 c.c. respectively. If desired agar plates may be used at the same time for the purpose of rendering easy the qualitative determination of the bacterial content of the water.

The Boston method of bacteriological examination of milk.—The routine of bacteriological examination of milk adopted by the Boston Board of Health may well be given in this connection as an example of a system that has been well considered and carefully worked out.

This method is based on the consensus of opinions given by the bacteriologists of fifteen prominent laboratories engaged in the examination of milk. The method has been well described by Slack.

The samples of milk for examination are transferred to test tubes by the use of large sterile pipettes, and a copper carrying case with double walls and felt inside has been adopted for the transportation of the samples in the test tubes. During the transportation of these samples the milk is maintained at a temperature of 34 degrees F. For routine work a dilution of 1 to 10,000 has been found most satisfactory. In the examination of fresh samples from individual cows or from milk known to be relatively pure the sample is diluted only 100 times and for milk which is suspected of being excessively contaminated a dilution of 1 to 1,000,000 has been adopted. The water used for dilution is kept in square 8 oz. bottles, which have been found very convenient to handle and economical of space. The medium used for bacteriological examination is agar-agar. The addition of lactose or litmus to the medium has apparently not given any special advantage in the tests which were made by the Boston Board of Health. Gelatine is not used for the reason that a long time must elapse before a report can be made, and difficulty is experienced in keeping it at a uniform temperature and preventing liquefaction. In the Boston system of milk examination the agar plates are incubated for twenty-four hours in a saturated atmosphere at 37 degrees C.

The counting apparatus as described by Slack is of a very simple construction. A circle 4½ inches in diameter and divided into 10 equal segments is cut into the surface of an ordinary school slate, after which the lines are filled with red lead. If the slate becomes gray with use it may be blackened by rubbing with vaseline. The Petri dish is uncovered and placed bottom down over the circle, after which it is covered with a wooden box open at the bottom, with a glass front and four inch circular opening at the top, the wooden parts being painted black to avoid refraction of the light. A four inch reading glass with a magnification of about two diameters fits over the opening of the box and keeps a constant focus, thus leaving both hands of the inspector free.

In Boston the Board of Health condemns milk on account of the presence of streptococci if a microscopic examination of the milk sediment shows the presence of streptococci or diplococci or cocci; and if the agar plate inoculated from the same sample shows apparent colonies of streptococci in excess of 100,000 per c.c. and broth cultures from these colonies show streptococci alone or in excess of other bacteria.

CHAPTER XIII.

TRANSMISSION OF INFECTIOUS DISEASES BY MILK.

Milk may be an important agent in the transmission of disease to man. Pathogenic bacteria may gain entrance to milk by direct secretion with the milk from diseased cows; from wounds, sores, or ulcers on the teats or other parts of the body of cows; from dust or other filth which may fall into the milk or become lodged on milk utensils; from diseased milkers; or from infected water used in washing cans and other utensils. As indicated in the discussion of the bacteriology of milk, bacteria find an unusually favorable nutrient medium in milk. After once getting into the milk they multiply rapidly, retaining their virulence completely. If, therefore, milk is allowed to become contaminated with disease germs it is a dangerous food for man and other animals, particularly calves and pigs.

It is apparent that milk may become infected with and may carry not only diseases which affect cattle and other animals, but also many human diseases, such as typhoid and scarlet fevers, diphtheria, septic processes, etc. The most important animal diseases which may be transmitted to man through milk are tuberculosis, foot-and-mouth disease, cowpox, anthrax, actinomycosis, septicemia, enteritis, etc.

The whole movement in favor of improved methods for managing dairy herds and in handling milk is based on the recognized danger to human health from an uncontrolled milk supply. If disease could not be transmitted in milk the most urgent reason for inspecting milk would be removed. It has been definitely proved, however, that a number of diseases may be transmitted to man in the milk of diseased cows or by means of milk which has become contaminated after removal from the cow. In this connection the only point about which there is essential difference of opinion is the actual extent and frequency of such transmission. The question thus raised must be answered somewhat differently in the case of different diseases, but in general, there is more likelihood of underestimating than of overestimating the danger from using milk which contains pathogenic bacteria.

Tuberculosis.—The prevalence and almost universal distribution of tuberculosis among cattle places this disease at the head of the list of infections which may be transmitted by milk. The fact that tubercle bacilli occur in milk has been known and the possibility of such occurrence was pointed out by Virchow and Koch in 1882. Since the first proof of the secretion of tubercle bacilli in the milk of tuberculous cows there has been much controversy concerning the conditions under which milk is infectious.

The direct proof of the infectiousness of cow's milk for man could be obtained only by means of feeding or inoculation experiments with man. Obviously such experiments are out of the question. We must depend, therefore, on accidental infection through wounds, cases of intestinal tuberculosis in children and adults, and other clinical evidence. The infectiousness of milk may best be demonstrated by feeding or inoculation experiments with calves, pigs or laboratory animals.

In attacking this problem the first question to be determined is whether the milk of tuberculous cows contains tubercle bacilli and, if not, whether the conditions under which they are not found in the milk may be defined. Both parts of this question must be answered in the negative. The milk of tubereulous cows does not always contain the bacilli of the disease. In general the bacilli are not found in the milk in the early stages of the disease. When the udder is affected the milk is almost always infectious. Likewise in advanced stages of the disease and in cases of generalized tuberculosis the milk usually contains the bacilli. In milk from the same eow they may be absent one day and present the next. Even if the milk in the early stages of the disease be eonsidered safe, it is impossible to prediet when it will become dangerous. In fact no general statement can be made as to the time when it is likely to become infeeted. The milk of all tuberculous cows must therefore be condemned as abnormal and dangerous even if no physical symptoms of the disease have appeared and diagnosis is made entirely by the aid of tuberculin. So long as the tubercles in affected cows are walled in or surrounded by a capsule of connective tissue there are no bacilli in the blood or milk except in cases of mammary tuberculosis. Whenever a tubercle breaks down, however, bacilli escape into the blood and from there readily gain entrance to the milk. As the tubereles become more numerous and more generally distributed throughout the body, individual tubercles break down more frequently and the milk is infectious a greater part of the time. This point may be fairly summed up by saying that in the early stages of the disease, or so long as physical symptoms are absent the milk is usually free from tuberele baeilli, while in cases of mammary tuberculosis or in advanced stages with physical symptoms the bacilli are likely to be found in the milk. For present purposes it is unnecessary to give details of the results obtained by the numerous investigators who have busied themselves with this problem. The experiments of Bollinger, Ostertag, Ernst, Martin, Woodhead, Bank, Johne, Mohler, Baumgarten, et al., indicate that in 15 per cent to 70 per cent of tuberculous cows the milk is infectious.

At the Storrs Experiment Station, Phelps kept 4 tuberculous eows under observation for 4 years and their milk was fed to calves without previous pasteurization, and for periods of 12-18 months. During the first two years only one case of tuberculosis developed among the calves. The results obtained during the next 18 months were quite

different. During this time 5 calves were fed the milk of the same cows and all 5 became tuberculous. At the beginning of the fourth year of the test 3 of the cows began to decline but the other appeared to be in good health. This experiment is mentioned merely as one illustrative example among hundreds. Phelps concludes from it that the danger of the spread of tuberculosis through the milk of infected cows is not as great as generally supposed. This conclusion, however, is unjustified except when restricted to the early stages of the disease.

Marshall in Michigan found that pigs could be fatally infected by feeding them milk containing tubercle bacilli. Pigs and calves were similarly infected by Russell. Mohler carried on an extensive series of feeding and inoculation experiments with the milk of 66 tuberculous cows. These cows gave a reaction to tuberculin but did not have an affection of the udder. In 21 per cent of the cows, however, the milk was infectious. The number of bacilli in the milk of these cows varied from day to day without assignable cause. Ravenel found that the milk of cows which merely reacted to tuberculin but showed no physical signs of disease may be virulent for guinea pigs in 15 per cent of cases.

Rabinowitsch and Kempner obtained similar results. On the other hand Ostertag succeeded in infecting guinea pigs with the milk of only one out of 50 reacting cows which showed no clinical evidence of tuberculosis. Ostertag therefore considers the milk of such cows harmless. These results in turn are interpreted quite differently by other investigators who assert that larger samples should be taken of such milk since the bacilli may be very scarce, and may be entirely absent in one small sample.

Ostertag found that the alarming increase of tuberculosis among hogs in northern Germany was connected with the increase in the number of creameries and was caused by the raw by-products of the creamery, especially the separator slime. Separator milk and buttermilk also serve to spread the disease among calves. Falk found that all the hogs fed by creamery owners and milk dealers were tuberculous. Borgeaud observed a regular enzootic among pigs fed on separator milk. No further cases appeared after the practice of boiling milk before feeding was adopted. Similar conditions have been observed by other investigators. The point under discussion may be summed up in the statement that the milk of tuberculous cows is the chief source of tuberculosis in calves and pigs.

In the previous discussion we have shown that the milk of tuberculous cows may, and, in a large percentage of cases, does contain tubercle bacilli; and that the bacilli are virulent and produce tuberculosis in calves, pigs, and laboratory animals when inoculated or fed with such material. Tuberculous milk serves to spread tuberculosis among live stock and is therefore unfit to feed to calves, pigs, and other animals. We have now to discuss the question whether it is also dangerous to man.

This question has been answered in every possible way. Koch says that the danger is so slight that milk may be disregarded as a source of human tuberculosis. In his opinion milk almost never transmits the disease to man. At the other extreme we have von Behring who asserts that "the milk fed to infants is the chief cause of tuberculosis." The great mass of students hold opinions between these extremes.

The question of intertransmissibility of bovine and human tuberculosis has been unnecessarily complicated by connection with the question of the unity or duality of tuberculosis. From the time of Koch's discovery of the tubercle bacillus until 1898 it was generally considered that there is but one species of this organism affecting man, cattle and other domesticated animals. During this time it was firmly believed that tuberculous human attendants were a source of danger to cows and similarly that the disease might be conveyed to man in the milk of tuberculous cows. In 1898 Theobald Smith published some experiments indicating a racial difference among tubercle bacilli. A human and a bovine form were recognized. In 1901 Koch announced his belief in two distinct forms of tubercle bacilli. Koch's position that human tuberculosis could not be transmitted to cattle and that tuberculous milk was not dangerous to man was immediately attacked by other investigators who were present at the London Congress on Tuberculosis. Since that date literally thousands of articles have appeared in nearly all of which Koch's views have been strongly combated. The majority of investigators hold that human and bovine tubercle bacilli although differing in virulence and sometimes in appearance, are nevertheless of the same species and show merely varietal differences.

In 1903-1907 Raw published the results of his observations to the effect that there are two distinct kinds of tuberculosis and that man is susceptible to both. Raw made a study of more than 4,000 cases of pulmonary tuberculosis in man in which the lesions were strictly confined to the lungs in all except 14 cases. The lungs were sometimes found to be infected simultaneously with two kinds of tubercle bacilli, one more virulent than the other. Raw believes that most cases of pulmonary consumption in man are acquired by infection from other human tuberculous patients, while primary intestinal tuberculosis and other tuberculous affections of the serous membranes in children are probably of bovine origin, produced by milk and not related to human tuberculosis. On account of the fact that the two forms of tuberculosis are rarely seen together it has been assumed that they are mutually antagonistic to each other, and that bovine tuberculosis may confer immunity to the human form of the disease.

According to the announcement of the German commission for the study of tuberculosis these investigators have found that 2 distinct forms of tubercle bacilli, the human and the bovine, must be recognized. It is held that in a majority of cases human tuberculosis is

contracted from man. Quite recently Smith published a summary of his investigations along this line for the last 5 years in which he presents fresh evidence of essential differences between human and bovine tubercle bacilli. The two types of bacilli were obtained from human mesenteric glands and showed characteristic differences in morphology and virulence. Smith believes that mammals other than cattle are probably infected from cattle or man or perhaps from both sources. The idea that there are 2 forms of the disease both of which may affect man appears therefore to rest on a firm basis at present.

That the milk of tuberculous cows may carry infection to man is thus admitted by all investigators of this problem. Koch and his disciples say that such transmission is rare but they concede the fact of transmission. It is therefore quite unnecessary that practical measures for the santary control of milk should be held in abeyance until the technical question of the unity or duality of tuberculosis is settled.

We may now proceed to a brief discussion of the methods of infection of man with tuberculosis. In the first place it is generally acknowledged that tuberculous milk is not always harmful for adult man. The alimentary tract of the adult appears to be somewhat protected against infection with tubercle bacilli. If, however, the mucous membranes are abraded or weakened by disease, infection may readily take place. The case is quite different with children. The human infant like the young of most animals is exceedingly susceptible to infection through the intestinal walls, which readily permit the passage of tubercle bacilli. Statistics were collected for the city of Stettin which showed that for the first year of life the mortality was 473 per 1,000, while at the age of 10 years it was 3 per 1,000, in other words the mortality was about 160 times as great for the first as for the tenth year of life.

The percentage of tuberculous infection in children follows a curve which corresponds with the importance of milk in the diet. According to statistics collected by Heubner the following percentages are observed: Under 3 months of age 0 per cent, at 3-6 months 3.6 per cent, at 9 months 11.8 per cent, at 1 year 26 per cent. Thereafter the infection decreases to 5 per cent at the age of 7-10 years. These figures indicate the close connection between milk and the tuberculous infection in children. In a study of 300 cases of the infantile form of tuberculosis known as tabes mesenterica Raw found that every case occurred in a child which had been nourished for a considerable period on cow's milk and not one in a child which had been nursed exclusively at the mother's breast.

In weighing the evidence in this problem it should always be remembered as pointed out by von Behring that tuberculosis is a slow infection. It may be months or years before the disease is recognizable. By that time the circumstances surrounding infection may be entirely forgotten. The length of the period during which the

disease remains latent depends upon the virulence of the virus, the number of bacilli introduced and the acquired susceptibility of the person due to colds, unfavorable weather, poor food, insanitary housing, overwork, etc. If as a result of these secondary causes operating upon the adult person pulmonary consumption appears, this may be due to an infection received from milk in early infancy. In fact in von Behring's opinion this is true in a majority of cases.

Again, attention should be called to the great difficulty of identifying cases of primary intestinal tuberculosis in children. The opinions of different investigators are much at variance on this point Moreover, the percentage of intestinal tuberculosis and tabes mesenterica in children apparently varies in different countries. In England tabes mesenterica constitutes 46 per cent of the total cases of tuberculosis for the first year of life and 36 per cent under 5 years of age. In Paris, Berlin, New York, Chicago, and Boston, however, the percentage of abdominal tuberculosis is much smaller. But since many investigators are willing to admit that it is practically impossible to identify the primary lesion these statistics are not very reliable. They fail to show the method of infection for the reason that the tubercle bacilli may cause no lesion at the point of entrance, but perhaps in some organ quite remote from that point. Ravenel and others have shown that when dogs are given tubercle bacilli with their food the bacilli may be found in the chyle and mesenteric glands within 1 to 4 hours. The gastroenteric mucous lining is readily permeable in young animals. Disse found that the mucous lining of the stomach is thin in newborn animals and becomes thicker with age.

At the Ohio Experiment Station Thorne collected the opinions of 339 practicing physicians on the infectiousness of the milk of tuberculous cows. The majority of these men had observed cases of infantile tuberculosis the source of which was apparently milk. Most of the physicians with country practice thought that the milk from one cow was safer for infants while most of the city physicians preferred mixed milk. This difference of opinion is doubtless due to difference in environment. Recently the Bureau of Animal Industry has infected monkeys by feeding them tuberculous milk. On account of the close zoological relationship between man and monkeys this experiment in itself furnishes almost direct proof of the transmissibility of tuberculosis from cattle to man.

What then shall be done with the milk of tuberculous cows? An unprejudiced review of this question indicates clearly that such milk may transmit tuberculosis to infants and to pigs, calves, and other domesticated animals. In thickly settled localities 50 per cent or more of the dairy cows may be tuberculous and the extent of tuberculosis among adult human beings is estimated by different authors between 40 per cent and 95 per cent. These percentages may be much reduced in both animals and man by preventing infection through the alimentary tract. It is therefore a highly important matter to pre-

vent the use of raw tuberculous milk as food for man or domesticated animals.

It is hardly necessary to call attention to the fact that the more numerous the bacilli in milk the greater the likelihood of infection. The danger is especially great in cases where an infant drinks the milk of a single tuberculous cow for a long period. In the mixed milk of a herd the tuberculous milk, if such cows are present, is more or less diluted with the milk of healthy cows. The danger of infection is thereby diminished for any given individual who drinks the mixed milk but is presented to a much larger number of persons, among whom susceptible ones may well be found. In advanced cases of mammary tuberculosis Ostertag has recently shown that the milk is infectious when diluted to the extent of 1:1,000,000. It is thus apparent that one tuberculous cow may render highly infectious the milk of a whole dairy or all the milk with which it could possibly be mixed.

Tubercle bacilli do not multiply in milk or at any rate such multiplication is so slight as to be negligible for practical purposes. They retain their virulence, however, without noticeable attenuation for long periods, much longer than milk will keep. In fact virulent tubercle bacilli have frequently been found in butter and cheese. It must also be remembered that milk may become contaminated with tubercle bacilli from tuberculous attendants or from insanitary handling. No data are available regarding the frequency of such contamination. Mohler and Schroeder have shown that the feces of tuberculous cows nearly always contain tubercle bacilli, which may get into the milk.

Foot and mouth disease.—In cases of this disease the milk is nearly always virulent. The virus is either secreted with the milk or gains entrance into the milk from the vesicles on the teats and udder which are ruptured during the process of milking. According to Brown the milk presents few abnormal characteristics in the early stages of the disease. The specific gravity is somewhat lowered. Within 3 days, however, large granular masses of a brownish-yellow color and pus corpuscles appear in the milk. The yield of milk is greatly diminished during the progress of the disease.

The milk from cows infected with foot-and-mouth disease is very virulent for children and young animals to which it is given in a fresh, warm condition. Calves sometimes die quite suddenly as a result of sucking cows which are affected with the disease. Fatal effects have also followed the feeding of such milk to pigs. Adult man is not so readily infected and many cases are known in which the milk has been consumed without bad effects. The milk, however, is quite unfit for use since numerous epidemics of eczema contagiosa or apthous stomatitis have been caused by it. According to Johne many cases of "pneumonia" accompanied by eczematous eruptions, and often fatal to infants, occurred in localities where foot-and-mouth disease was

prevalent. Brussenius and Siegel collected data on 16 epidemic outbreaks of the disease in man which occurred from 1878-1896. Nearly all cases resulted from drinking unboiled milk. In 3 of the outbreaks 75 deaths occurred. The German Imperial Health Office compiled an account of 172 cases in man, 66 of which were due to milk and 1 to butter. Hertwig and 2 medical friends demonstrated the infectiousness of such milk by drinking it for a period of 4 days, one quart daily each. Within 2 days the symptoms of the disease appeared in the form of fever, headache, pains in the legs, and an itching sensation. After 5 days the mucous membranes of the mouth became swollen and numerous blisters appeared on the tongue, lips, and cheeks. After a few days the vesicles ruptured, leaving red, slowly healing, ulcers which persisted for about 5 days. In one case blisters appeared on the hands and fingers, producing ulcers which required a much longer time for healing than those in the mouth. Sometimes a conjunctivitis is observed and blisters may appear on the nose, ears, and other parts of the body. There may also be violent vomiting, diarrhea, and erythrism of the skin especially in children, and often with fatal results.

The literature of veterinary and human medicine contains numerous accounts of the transmission of foot-and-mouth disease to man through the milk of affected cows. Siegel had 6 deaths in 400 cases. The incubation period in these cases was apparently 8 to 10 days. Shivering, giddiness, and nausea appeared in a majority of cases. In some patients the teeth became loose, the breath was offensive, and hemorrhage occurred from the mouth and stomach.

In addition to the changes in the milk noted above Jensen reports that in advanced cases the milk becomes thin with a slimy cream, contains leucocytes and gland cells in unusual numbers and sometimes red blood corpuscles. The albumin and globulin appear to increase in quantity while the amount of casein and milk sugar diminishes.

The milk appears to be most infectious when freshly drawn and its virulence gradually diminishes. An outbreak was reported by Hart in Aberdeen in which the skim milk was not virulent. The virus may be present, however, in the skim milk, buttermilk, butter, or even cheese. Schneider and other German investigators have clearly demonstrated the infectiousness of these products from cows affected with foot-and-mouth disease. Fröhner investigated a case in a man who ate sweet butter from the milk of such cows. The disease appeared within 48 hours and ran the usual course with numerous blisters in the mouth and on the face and ears. Vincent observed a number of cases in children in which only the throat was affected, with symptoms similar to those of scarlet fever.

The virus of foot-and-mouth disease is not very resistant. Milk is rendered non-infectious by subjection to a temperature of 70°C for 10 minutes, or by being boiled. Pasteurizing at 80°-85°C. is efficient according to Danish experience. On account of the extensive physical and chemical changes which the milk undergoes during the progress

of foot-and-mouth disease it can not be considered as fit for man even after boiling. In the outbreak of the disease in New England the sale of milk was stopped as soon as the disease appeared and little opportunity was given for transmission to man.

In the city of Lawrence, Massachusetts, however, Brush traced 5 cases in children directly to the use of infected milk. The disease had existed for some time in the dairy which supplied the milk before the premises were visited by the veterinary authorities. The symptoms observed in the children were fever, vomiting, diarrhea, swelling of the tongue and the eruption of blisters in the mouth. Such milk should not be fed to infants at all and before being fed to calves, pigs, or chickens it should be boiled.

Anthrax.—The bacilli of anthrax have been demonstrated in milk by Feser, Monatskov, Chamberland, Roux, Nocard, and others. F. Baum not only found anthrax bacilli in the milk of cows suffering from the disease, but showed that such milk was infectious for small laboratory animals. He concludes, therefore, that the use of this milk is attended with great danger. In studying the behavior of anthrax bacilli in milk Caro found that in freshly drawn milk they increased for the first 3 hours and then diminished in numbers. They lost their virulence within 18 hours at a temperature of 37° C. and within 24 hours at 15° or 16° C. This fact is attributed to the formation of acid in the milk. When magnesium oxid was added and no free acid allowed to develop for 24 hours the bacilli multiplied rapidly and retained their virulence. According to Miquel and Cambier the anthrax bacillus develops rapidly in milk, changing it within a few hours into a solid, clotted mass, surmounted by a clear alkaline liquid. If, however, the milk is in a thin layer and freely exposed to the air coagulation is not produced by the anthrax bacillus.

Heusinger claimed that the milk of cows suffering from anthrax had been shown to be virulent for man by numerous observations in the United States and Russia. Heusinger, however, considered milk sickness as a human form of anthrax. On this point he was evidently in error, since these two diseases are recognized as distinct by all American writers. Williams says that malignant pustule in man may arise from using the milk and butter of affected cows. Intestinal infection with anthrax is rare in man and appears as an inflamed condition of the intestines and mesenteric glands. Outbreaks of anthrax have occurred in Delaware and Wisconsin and the disease appears to be permanently established in the Gulf States, especially in Mississippi. No authentic proof has been presented from these outbreaks, however, of the transmission of anthrax by means of the milk. Nevertheless, it is reasonably certain that anthrax bacilli may penetrate the intestinal mucous membranes of children and infected milk must therefore be considered dangerous. The anthrax bacillus does not appear in the milk until the disease is far advanced. The milk may then become bloody and is otherwise altered so as to be

unfit for use. Moreover, the symptoms of anthrax are so pronounced that there is no excuse for failure to recognize the diseased condition and to exclude the milk from sale and also from use even for domesticated animals except after sterilization by heat. If proper care is exercised it is safe to permit the use or sale of the milk from healthy animals in a herd in which a few cases of the disease have occurred. If, however, the conditions are insanitary such milk is dangerous; for the feces and urine of diseased animals may infect the stables and in this way anthrax bacilli may gain entrance to the milk during the process of milking or later in handling.

Cowpox.—The teats are the usual seat of cowpox lesions. The vesicles formed during the course of the disease may easily become ruptured in milking and the virus may thus gain entrance to the milk. Whether or not the virus is ever secreted directly with the milk is not known. The disease is readily transmitted to man, especially to the hands and face. There are but few authentic instances, however, of transmission by means of the milk. The infrequency of transmission may be due, as Jensen suggests, to compulsory vaccination and the consequent immunity of man except to local infection in abrasions of the skin on the hands and face. The virus is quite resistant and man is naturally susceptible. In Edinburg two outbreaks of sore throat occurred in a boys' college and involved 134 cases. The symptoms were headache, lassitude, bleeding at the nose, fetid breath, gastric disturbances, red and swollen patches on the mucous membrane of the mouth, etc. These epidemics were traced to the milk supply and were successfully checked by boiling the milk. One veterinarian diagnosed the disease in the cows as cowpox; another dissented from this opinion. In an outbreak described by Stern cowpox appeared in a dairy herd. Among the children who received this milk an epidemic appeared in the form of skin eruptions which healed with the formation of scales. In cases of cowpox the milk may become thin, of bluish color, and readily coagulable. One attack of cowpox in man gives protection against further attacks of the disease and also against smallpox.

Rabies.—The virus of rabies is found in the nervous system, salivary glands, saliva, bronchial mucus, and milk. Peuch, Nocard, Perroncito, Bardach, and others have shown that the virus may be excreted with the milk. In one case it was found that the milk of a rabid woman was infectious for rabbits and guinea pigs but not for her child. Rabies can not readily be transmitted by infection through the alimentary tract. Numerous experiments have been made in feeding the milk of rabid cows to laboratory animals. Negative results have been obtained in all cases. The digestive juices may render the virus harmless. There is always the possibility, however, of infection through a decayed tooth or through abrasions of the mucous membrane of the mouth and pharynx. The milk of rabid animals should not be used for any purpose.

Tetanus.—No evidence has been presented to show the transmission of tetanus through the milk. Infection may take place, however, through the walls of the alimentary tract if lesions are present. The spores of tetanus may gain entrance into the milk from fecal matter in stables. The milk of cows affected with tetanus should not be used. Ordinarily such cows will not be milked.

Pleuro-pneumonia.—It has not been definitely determined that man is susceptible to this disease in any form. The milk from affected cows quickly separates into cream and serum-like layers. The fat content diminishes and the albumin increases in amount. These changes furnish sufficient reason for prohibiting the use of the milk. No case of pleuro-pneumonia has been known in the United States since the disease was eradicated by the Bureau of Animal Industry. In Europe several cases have been reported in which children developed symptoms of pneumonia and other pathological conditions after drinking milk from affected cows. In a few instances the lesions closely resembled those of pleuro-pneumonia in cattle. The fact remains, however, that the virus has never been found in the milk. If an outbreak of the disease should occur the necessary quarantine measures would be so strict as to prevent the use of the milk.

Actinomycosis.—This disease is of quite common occurrence in the udder of cows. It occurs still more frequently in the sow's udder. The human form of the disease appears to be identical with that observed in animals. It is generally believed that the ray fungus which causes this disease is found on cereals, grasses, and other food plants, and gains entrance to the animal organisms through skin wounds or through the alimentary tract. Accordingly the majority of cases in man are probably acquired in the same way as those in animals. The ray fungus has never been demonstrated in milk. Nevertheless when the disease occurs in the udder, especially in the primary form, the organ is greatly altered by the formation of tubercles throughout its substance. The actinomycotic processes may slowly extend to the outside of the udder and form running sores. It is apparent, therefore, that the milk may become infected in the udder or in the process of milking, from the sores on the udder. Man may become infected through decayed teeth or lesions in the digestive tract. The milk of actinomycotic cows should therefore be excluded from the market.

Milk sickness.—The nature and etiology of this disease have never been well understood. Fortunately the disease is yielding to better cultivation of the soil and drainage of marsh lands. Heifers, steers, and bulls show pronounced symptoms. Cows in full lactation, however, show no symptoms of the disease although their milk may be exceedingly virulent. Calves, pigs, and man are affected by drinking the milk. Calves and pigs tremble, vomit, and frequently die as a result of the disease. In man the symptoms are weakness, loss of appetite, nausea, thirst, coated tongue, cold dry skin, offensive breath,

slow respiration and weak pulse. According to Law the temperature is often subnormal and never higher than 100°F. Chills and headaches do not occur. The bowels are inactive. The patient is apathetic and finally passes into a comatose condition, dying without a struggle. In many cases a complete but slow recovery takes place. The mucous lining of the stomach and intestines is inflamed and sometimes sloughs off in patches.

Infected cows which do not show any pathological symptoms while at rest may be made to do so by driving for a short distance. They will then tremble and the disease may be recognized. Infected timber land should be partly cleared so as to admit the sunlight freely. Infected marsh land should be drained and planted to cultivated crops. This will check the disease among cows. The milk of cows which graze on infected pastures should never be used except after boiling or pasteurization.

Mammitis.—The effect of the presence of mammitis upon the quality of the milk depends upon the form and stage of the disease. Mammitis or garget of cows may be due to infection with streptococci, staphylococci, or bacilli of the coli-aerogenes group. The gland is affected with simple catarrhal, purulent, or gangrenous processes. Abscesses are frequently formed and ordinarily pus and disintegrated tissue escapes with the milk. Naturally, large numbers of bacteria are found in this purulent material together with fibrin and other elements of the blood. Catarrhal mammitis affects the milk ducts. Their secretions thus become like bronchial mucus in cases of bronchitis. In parenchymatous mammitis the minute lactic canals, acini, and connective tissue are involved. The milk of affected quarters assumes a yellow color and has numerous clots in it. The milk from unaffected quarters soon shows the same changes and also becomes sticky. Later large quantities of pus are discharged with the milk, which becomes purulent and full of shreds of dead tissue. The milk from cases of mammitis is therefore utterly disgusting, quite aside from the consideration of any danger of infection which may be involved in drinking it. The presence of pus gives the milk a disagreeable flavor and makes it coagulate quickly. It is probable also that the pus is harmful to young children. Moreover, the streptococci and staphylococci which occur in milk from cases of mammitis have been shown to be virulent when taken in the alimentary tract.

Niven, Holst, Johannesen, and others have reported several hundred cases in which human beings suffered from severe gastric and intestinal catarrh as a result of drinking milk from cows affected with garget. In all instances streptococci were found in the milk. The milk proved harmless when boiled. The milk of goats affected with gangrenous mammitis may also cause chills, headache, and vomiting. As shown by Moro such milk may be virulent even when used in small quantities in coffee.

Streptococcic sore throat.—This disease is often due to direct milk infection. Thus Edwards and Severn traced several cases of follicular tonsillitis to milk. The temperatures of the patients ranged from 100° to 103° F. and there was great prostration in a few cases. In the dairy herd which supplied the milk only one cow gave infected milk. In this cow's milk great numbers of staphylococci and streptococci were found. The milk also contained considerable quantities of pus. The micro-organisms persisted in the milk of this cow for a long time and the same species were found in all the cases of sore throat. Numerous cases of this sort have been reported in medical literature. In the majority of such cases, however, no direct evidence was secured of a causal connection between mammitis in cows and sore throat in the human patients. The possibility of infection of the milk after it was drawn was usually not excluded. In all cases of mammitis the milk may contain pus and is therefore abnormal and highly objectionable. Moreover, in the infectious form of the disease the micro-organisms are virulent and harmful for man. From a clinical examination it is impossible to determine whether or not such virulent bacteria are present. It is necessary, therefore, to exclude from the market the milk from all cows affected with mammitis. This exclusion should apply to all of the milk from each affected cow. The disease tends to spread through the udder and an abscess in a diseased quarter may at any time break through into an apparently healthy quarter. The milk from these quarters may thus become infected in the udder. Furthermore, even if such extension of the pathological process has not taken place, the milk from the healthy quarters of the udder may readily become contaminated by carelessness in milking. Frequently the diseased quarters are milked first and then the healthy quarters, and without washing the hands. Often, too, the secretion of diseased quarters is milked upon the floor. Such practices can not be too strongly condemned. The streptococcus of bovine mammitis develops rapidly at temperatures of 16°-30° C. and occurs in enormous numbers in the milk of affected cows.

Milk fever.—Although the essential nature of this disease has not been established it seems desirable to refer briefly to some recent observations regarding the toxicity of the milk of affected cows. According to Dehmer the milk rapidly separates into 2 layers, the upper of which is thick and yellowish and occupies about one-fourth of the height of the column. The lower portion is of a bluish-white color and contains numerous colostrum corpuscles. Such milk was found to cause the death of healthy cows when inoculated intravenously. It proved virulent also for rabbits. From these experiments it appears that the toxic cause of milk fever may be found in the milk. At any rate there is no excuse for using such milk.

Hemorrhagic enteritis.—This disease occurs much more frequently in calves than in adult cows. Jensen has shown that this affection is usually due to bacteria which belong to the hog cholera group. It is

not known whether the micro-organisms of this disease are directly transmitted with the milk. On account of the profuse diarrhea, however, the posterior parts of the cow and the floors become thoroughly contaminated and the bacteria may thus easily gain entrance to the milk. Follenius and Gaffky have reported cases in which the milk from such cases was shown to be virulent for man, producing headache, fever, weakness, and diarrhea.

Septic diseases.—In so far as the meat is concerned septicemia is the most dangerous to human health of all animal diseases. A large percentage of the most violent cases of meat poisoning are caused by eating the meat of animals suffering from septic processes. No authentic instances are on record of the transmission of septic affections by means of milk. It is highly probable, however, that such transmission does occur.

As an example of this class of diseases we may mention septic metritis or inflammation of the uterus. In such cases the uterine exudate containing streptococci, staphylococci, coli bacillus, and proteus soils the posterior parts of the cow and may easily gain entrance into the milk. Milk containing these bacteria would be virulent for man, as well as for calves and pigs.

It is likewise almost impossible to prevent contamination of the milk in cases of retention of the afterbirth. Septic bacteria are not always present in these cases. The milk should not be used until the uterus has resumed its normal condition and until the cow has been properly cleaned.

Suppurating wounds, and phlegmonous, or erysipelatous processes in the skin, especially on or near the udder, give occasion to the almost certain contamination of the milk. The bacteria which thus fall into the milk along with other filth may cause enteritis in man.

Moreover, the epizootic prevalence of septic calf lameness, calf dysentery, white scours, or calf diphtheria furnishes favorable conditions for the contamination of the milk. In herds in which such diseases prevail the milk is not fit for infants unless affected animals are isolated and all necessary sanitary precautions observed.

There are a number of other malignant diseases of cows, such as hemorrhagic septicemia, rinderpest, malignant edema, malignant catarrhal fever, broncho-pneumonia, etc., in which the possibility of infection of the milk can not be excluded. In all diseases accompanied with fever more or less serious metabolic disturbances occur and toxic substances may be found in the milk. The progressive dairyman in order to build up and preserve a good reputation for his milk and protect the health of his patrons will exclude the milk of all cows which are suffering from any acute disease. Milch goats affected with Malta fever may transmit the disease to man in the milk.

In a study of the excretion of micro-organisms through the active mammary gland it should be remembered that in general those bacteria which have the power of producing hemorrhage or similar

changes in the mammary gland during which the normal structure of the organ is disturbed are most likely to be excreted in the milk. Mixed infection favors the excretion of bacteria from the udder. Thus in cases of pure septicemia or anthrax the pathogenic micro-organisms are less frequently found in the milk than when associated with *Bacillus bovis morbificans* or some other organism with similar properties.

Pathogenic bacteria may be present in considerable numbers without causing any changes in the milk. On the other hand *Bacillus coli* may rapidly and completely sour and coagulate the milk, *Proteus vulgaris* may decompose it, and *Bacillus enteritidis sporogenes* may cause a decomposition and formation of gas. In this connection it is important to know how long disease germs may retain their virulence in milk. According to Dawson the bacillus of swine plague becomes attenuated in milk within 36 hours and loses its virulence entirely within 72 hours. This effect is apparently due to the acid formed in the milk. Dawson found that in butter the tubercle bacillus retains its virulence quite uniformly for 3 months, after which it becomes gradually attenuated but is still virulent at the end of a period of 8 months. As a rule bacteria thrive best in a neutral medium. They are therefore somewhat unfavorably affected by the souring of milk. Milk, however, is usually consumed in a fresh condition.

The foregoing discussion has been concerned with diseases which may be transmitted from cows to man through the agency of milk. We have now to consider the transmission of human diseases in milk as the result of infection or contamination of the milk after it has been drawn. The list of known milk-borne diseases is not very large. The most important are typhoid, scarlatina, diphtheria, and cholera.

There are certain general characteristics of milk-borne epidemics which greatly assist in the identification of the source of infection in milk. In the first place the distribution of such epidemics conforms with the route of a certain milkman. The disease prevails most extensively among the middle and upper classes who drink more milk than the poor. The upper classes live in more sanitary surroundings than the poor and are therefore less exposed to the usual sources of infection than the latter. Milk is at once to be suspected if typhoid or scarlet fever becomes epidemic among the upper classes of a certain section of a city. Milk-borne epidemics naturally prevail more extensively among the individuals who drink most milk. The apparent exemption from infection of certain members of a family is thus easily explained. As a rule women and children drink more milk than men and are therefore more affected in milk-borne epidemics than men. Newman has called attention to the fact that the period of incubation is much shorter in cases of typhoid fever, scarlet fever, and diphtheria when these diseases are carried in milk than when they arise from some other source of infection. Thus when conveyed in milk the first symptoms of typhoid fever may appear within a few days (sometimes 2 days) and those of scarlet fever and diphtheria

within a few hours. This is probably due to the fact that the virus of these diseases multiplies rapidly in milk and the victim receives much larger quantities of it than he would by any other method of infection.

Again in milk-borne epidemics the outbreaks occur suddenly. A large number of persons are affected at once or in rapid succession, much more rapid than could occur by infection from person to person. The outbreaks stop as suddenly as they begin. This follows as a result of excluding the infected milk from the market, boiling the milk, or from the extinction of the original source of infection. Finally, the symptoms in cases of infection from milk are less severe and the rate of mortality is lower than normal. Most cases are mild. Scarlet fever, when conveyed by milk, shows characteristic modifications in a large percentage of cases. Along with typical mild cases of scarlet fever there appear many cases in which the symptoms are confined to the throat. The true nature of such cases is often misunderstood and they are wrongly diagnosed as simple cases of sore throat. The symptoms of typhoid fever and diphtheria conveyed by milk do not differ except in mildness from typical cases. Milk-borne diphtheria is perhaps less contagious than cases due to other sources of infection.

It is obvious that milk may easily become infected with the virus of human diseases. The pathogenic organisms of these diseases are often present on the clothing of attendants or in their expectorations, feces, or urine during convalescence and even for long periods after recovery. If such attendants are careless in their habits it would be almost miraculous should the milk fail to become contaminated. Abundant opportunity for contamination is offered during milking, handling of the milk on the farm, transportation to market, bottling, distribution to individual patrons, and during subsequent care in the household. In connection with the study of an outbreak of typhoid fever in 1857 Taylor first demonstrated that milk may act as the vehicle of infectious human diseases. Since attention has been directed to this source of infection hundreds of outbreaks involving thousands of cases have been definitely traced to a contaminated milk supply. It is highly probable, however, that milk is suspected in only a small percentage of the cases in which it is the carrier of infection. In this regard the danger of an unregulated milk supply can not be overestimated.

Typhoid fever.—Extensive and classified lists of outbreaks of typhoid fever carried by milk have been collected by Hart, Freeman, Newman, Schuder, Kober, and others. Among 195 epidemics tabulated by Kober the disease prevailed at the farm or dairy in 148. In 67 outbreaks the milk became infected through the water with which the utensils were washed and in 16 instances infected water was used in adulterating the milk. In other instances the cows drank and waded in infected water, the dairy employes served also as nurses of

typhoid patients, or the patients continued at work while suffering from a mild form of typhoid. The seriousness of these epidemics is apparent from statistics collected by Hart, according to whom it appears that in 51 outbreaks of milk-borne typhoid there were 3,500 cases and 350 deaths.

It is easy to see how milk may become infected with the typhoid bacillus. It may be well, however, to discuss briefly some of the methods of such contamination. If milk utensils are washed with polluted water infection may readily be carried to the milk. In most instances infected water comes from wells and small streams. Both these sources of water supply are much exposed to pollution. Milk may be still more certainly and more extensively polluted by adding water to it for purposes of dilution or adulteration. Again milk may become contaminated by direct or indirect contact with typhoid patients. If the same person who nurses a typhoid patient also milks the cows, the hands may easily become infected and the typhoid bacilli may thus gain entrance to the milk. Many such cases have occurred and this fact serves to illustrate the danger to the public health from the non-regulation of the workmen and premises of dairy farms. At least two outbreaks of typhoid have been traced to infection of the milk by means of air carrying typhoid bacilli from dried excrement. This shows the importance of burning or otherwise disinfecting all excrementitious matter, including urine, from typhoid patients and also of protecting milk against contamination with dust. In another outbreak the milk utensils were wiped with a dish cloth which was also used among typhoid patients. Sealed milk cans sometimes leak when sunk in water for cooling purposes. One instance is known where the milk became infected in this way. When it is remembered that the feces and urine of typhoid patients may contain the bacilli during convalescence and for months after recovery it will be apparent how frequently opportunity for infection is offered and how varied the methods are by which such infection may take place. In recent years evidence has been accumulating regarding the agency of flies in the distribution of typhoid fever. Flies frequent feces. Fly maggots live in such material and adults feed upon it. They are also greatly attracted by all kinds of human food, perhaps particularly milk. Flies have been shown to carry typhoid bacilli on their legs and other parts of the body. It is obvious, therefore, that flies may carry the bacilli from human feces to milk and infect the latter. Other insects with similar habits may also be instrumental in spreading infection.

The typhoid bacillus thrives well and grows rapidly in raw or sterilized milk. It retains its virulence for long periods in milk and its products (according to Plaut, for 30 days in milk, 48 hours in buttermilk, 21 days in butter, and several days in cheese). Bolley inoculated milk products with typhoid bacilli for the purpose of determining how long they retain their virulence. Bacilli placed in small pits in salted butter remained virulent for 7 to 10 days. They remained

alive for several months in cream, buttermilk, and unsalted butter. In sweet milk the germs developed in great numbers and the milk became acid but did not coagulate. In mixed infection of milk the typhoid bacilli were not outgrown by other species but in some cases became predominant.

The bacillus does not sour the milk or alter its appearance in any way. It does not coagulate milk like the closely related coli bacillus which occurs more frequently in milk. Moreover, the typhoid bacillus does not form gases. Its multiplication is somewhat checked by the souring of milk but is not entirely stopped and its virulence is not thereby destroyed. According to Sternberg its virulence is destroyed by subjection to a temperature of 56°C. for 5 to 10 minutes. In milk the typhoid bacillus is destroyed by the ordinary process of pasteurization at 80°C. or even at 70°C. for a period of 10 minutes. Pasteurized milk is therefore a safe article of food in so far as typhoid fever is concerned. It must be remembered, however, that the milk may be become reinfected at any time through the agency of flies.

The commonest way in which milk becomes infected with the typhoid bacillus is through polluted water, and in adulterating the milk or in washing milk receptacles. Dairyman who desire to furnish sanitary milk to their patrons may easily avoid danger of typhoid infection by using for washing purposes water which has been boiled or by scalding all milk receptacles and exposing them to bright sunlight. If all typhoid feces and urine are destroyed the danger of transmission through the agency of flies will be removed. The sanitary disposal of typhoid excrementitious matter will also protect the water supply of the farm.

Scarlet fever.—Although the pathogenic micro-organism of scarlet fever is not known, it has been shown beyond reasonable question that the disease may be conveyed by milk. The most probable bacterial cause of scarlet fever is *Streptococcus scarlatinae.* In 99 epidemics of milk-borne scarlet fever tabulated by Kober the disease prevailed at the dairy or milk farm in 68 instances. In 6 outbreaks persons in some way connected with the dairy had been exposed to the disease. Moreover, in 17 instances the milk became infected from contact with attendants who were convalescing from the disease. Finally in 19 outbreaks infection was attributed to disease of the cows (puerperal fever, ulcers on the teats, etc.). In nearly all epidemics of milk-borne scarlet fever evidence has been produced that individuals actually suffering with the disease or carrying the contagion on their clothes have taken part in milking or distributing the milk to patrons. On account of the highly infectious character of scarlet fever it is not difficult to understand how the milk may thus become contaminated. Nearly all these epidemics are reported from England and America. In continental Europe on the other hand physicians seem generally to doubt the importance of milk in the transmission of scarlet fever. This is

doubtless due in part to the fact that milk is more extensively pasteurized before using in continental Europe.

Attention has already been called to the fact that milk-borne scarlet fever is often mistaken for cases of ordinary sore throat on account of the fact that the symptoms may be almost entirely confined to the throat. As noted by Parsons, Buchanan, and others the rash may be of short duration and desquamation very slight. Moreover, nephritis as a complication is much rarer than after ordinary cases of scarlet fever. The vomiting and diarrhea frequently observed in the milk-borne disease are perhaps due to milk poisoning, since the infection of milk with scarlet fever furnishes good evidence of carelessness and insanitary handling of milk. The fact that this form of scarlet fever is not only slightly infectious may well be attributed to the small extent of skin eruption and desquamation, as suggested by Newman. It has also been observed that after drinking infected milk persons who have already had scarlet fever exhibit merely mild throat symptoms while others may suffer more severely. The virus of scarlet fever may be destroyed by sterilizing the milk or by ordinary pasteurization.

Power studied an outbreak of scarlet fever in London and came to the conclusion that it was transmitted by cows suffering with eruptions on the udder and teats. Klein obtained *Micrococcus scarlatinae* from the diseased tissue of these cows and succeeded in reproducing the disease in calves by inoculation. Thus far, however, no unexceptionable evidence has been produced that cows may become infected with scarlet fever or that the disease may be transmitted to man from diseased cows. Supposed cases of this sort may well be attributed to infection from some other source or may be referred to as pseudo-scarlet fever.

Diphtheria.—In a list of 36 milk-borne epidemics of diphtheria as tabulated by Kober the disease existed at the dairy farm in 13 instances while in 12 outbreaks the disease was attributed to direct transmission from cows suffering with mammitis or ulcers on the teats. The diphtheria bacillus thrives well in milk. It grows at all temperatures between 20° and 37°C. It grows more vigorously in raw than in sterilized milk. The bacillus has not been isolated from market milk except in a few instances.

The diphtheria bacillus is widely distributed and may possibly live for some time as a saprophyte in the soil. Moreover, it has been demonstrated that it may persist in the throat of convalescing diphtheria patients for a period of 8 weeks or perhaps longer. These facts serve to indicate how frequently milk may be exposed to infection as a result of carelessness in the personnel of dairy farms. Outbreaks of diphtheria due to drinking infected milk have occurred in England, Scotland, United States, Denmark, Sweden, Germany, and elsewhere. The diphtheria bacilli are not affected by the souring of milk and therefore probably occur in butter and other milk products. They are destroyed in milk by subjection to a temperature of 70°C for a period

of 10 minutes. The number of cases of diphtheria transmitted by milk is small as compared with those which arise from other sources of infection. It is evident, however, that many cases of transmission in milk escape notice and sufficient instances have been definitely ascertained to lend the matter considerable importance from the standpoint of human health.

Many cases have occurred particularly in England of apparent transmission of diphtheria directly from cows to man. In one outbreak of this sort Klein asserted positively that the diphtheria bacillus could be demonstrated in the milk of a diseased cow even when drawn under all antiseptic precautions. Klein states that the bacilli were present at the rate of 32 per cubic centimeter of milk.

In 1904 Chalmers reported an outbreak of septic sore throat and diphtheria among the staff of the Belvidere Hospital, Glasgow. In all, 39 cases with diphtheritic symptoms were observed. In a majority of cases it was impossible to understand how infection could have taken place from one person to another. In the dairy herd which supplied the milk an infectious teat eruption occurred and spread rapidly. The disease also affected the hands of the milkers. Chalmers believes that "there can be little hesitation in regarding the majority of the throat affections which came under observation at the hospital as directly resulting from the teat eruption." At any rate the outbreak stopped as soon as the milk was boiled.

Robertson traced a serious outbreak, diagnosed as diphtheria, to ulcers on cows' teats. The epidemic ceased as soon as the milk of the affected cows was excluded from sale. It was not possible to isolate the diphtheria bacillus from the ulcers on the cows' teats. It was suggested that the disease was cowpox.

Cows have been inoculated with the human diphtheria bacillus but no disease comparable with diphtheria has been produced in this manner. The relationship between human and bovine diphtheria is under dispute. Most investigators, however, are inclined to believe that the two diseases are distinct and unrelated. Septic sore throat may result from drinking the milk of cows with ulcerated teats, but the disease is probably not true diphtheria. According to the evidence now available it appears that diphtheria bacilli in milk must be considered as coming from cases of human diphtheria and as gaining entrance to the milk after it has been drawn.

Cholera.—The cholera vibrio thrives better in sterilized than in raw milk. It can not live in an acid medium and soon dies in sour milk and buttermilk. The number of authentic examples of transmission of cholera in milk is limited. Simpson reported the most striking outbreak of this sort. On board a vessel in the harbor of Calcutta 10 men drank some native milk which had been diluted with infected water. Of this number 4 died, 5 recovered after serious illness, and one, who drank only a small quantity of the milk, was only slightly affected. The cholera vibrio may be destroyed by boiling the

milk. It should be remembered, however, that boiling destroys all the common milk bacteria, and prevents the souring of the milk, thus furnishing the most favorable medium for the growth of cholera germs which may gain entrance to the milk after it has been sterilized. During cholera epidemics the milk should be boiled immediately before using.

Thrush.—Oidium albicans, the fungus which causes thrush, frequently occurs in milk. It thrives well in milk, and in this medium gains entrance to the infant's throat where the disease becomes established. Milk is undoubtedly an important carrier of this disease.

Diarrhea.—According to statistics collected by Newsholme only 9 per cent of the fatal cases of diarrhea in children occur in those which are fed at the breast. Numerous cases of diarrhea in adults accompanied with chills, fever, and general weakness have been traced to cows affected with enteritis, or to infection of the milk with bovine or human fecal matter. Such infection usually takes place by means of polluted water or dust. As noted above, diarrhea often appears in connection with sore throat as a result of drinking milk from cows suffering with mammitis. A considerable percentage of these cases of diarrhea are due to the excessive numbers of the coli bacillus commonly found in unclean milk. The prevalence of coli bacillus indicates fecal pollution and suggests the obvious remedy of grooming the cows and protecting the water supply.

Tuberculosis.—The transmission of this disease from cows to man has already been discussed. Tubercle bacilli may also gain entrance to milk directly from consumptives, particularly if they have careless habits. Tuberculous patients should not be employed in handling market milk, since they may spread contagion about the stables and may infect the milk directly by coughing.

Other diseases.—Milk has been shown to be a favorable culture medium for the pathogenic organisms or virus of various other diseases such as erysipelas, pneumonia, etc. The possibility can not be excluded that milk may serve to carry smallpox, measles, bubonic plague, syphilis, dysentery, cerebro-spinal meningitis, etc. Authentic cases of such transmission perhaps do not exist, but it is for obvious reasons a very difficult matter to demonstrate the causal connection of milk with outbreaks of these diseases.

It is not necessary or desirable to adopt an alarmist position with regard to the general question of the transmission of infectious diseases through the agency of milk. Indifference in this regard, however, constitutes a great source of danger to the public health. This danger has not been overrated in the above discussion. It must be admitted as highly probable that milk serves to transmit far more cases of infectious diseases than are definitely traced to the milk supply.

The prevention of the transmission of infectious diseases by milk may be largely effected by the following measures:

(1) Cleanliness of the cows, stables, fodder, attendants, all milk utensils, milk rooms, etc.

(2) The sterilization or pasteurization of milk, if it can not be consumed in a fresh condition or can not be refrigerated.

Moreover, in order to secure the best sanitary conditions for milk, it is necessary to carry on an increasing crusade for greater domestic and civic cleanliness with regard to the storage and handling of milk and the prevention of the dust nuisance and the fly nuisance.

CHAPTER XIV.

DIETETICS OF MILK WITH REFERENCE TO INFANT FEEDING.

BY

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The whole movement toward milk purification has received its impetus largely through the infant. This is true for several reasons. Although milk may be looked upon as a universal food, it is the young of all species who use it as their whole food. Adults among the poor practically never use it. Adults among the well-to-do use it most extensively in cooking, where it is harmless, but even when they use it raw they are not affected by the products of the dirt bacteria ordinarily found in such great numbers. So that for a long time it was thought that if no adulterations were used and the proper standards of total solids and fats were observed, the milk supply was as satisfactory as could be expected. With the advance in bacteriological methods and the more frequent recording of vital statistics, people awakened to the fact that babies were ill and dying in great numbers and that most of these babies were on food other than mother's milk, usually cow's milk. But it was a long time before public opinion was well aroused and even today most people are ignorant of the true conditions on the average dairy farm. Let us consider milk then from the standpoint of dietetics for infants.

Diet is the most important branch of pediatrics. Slight ailments of babies, as well as more serious diseases, find their source in food oftener than in any other one etiological factor. The younger the child the greater is the stress to be laid on the proper feeding as a relief from diseased conditions, for the younger the child the nearer is it to the perfect development with which the average child is endowed at birth and the less chance there is for the many diseases which come to it later from without.

Mortality.

At this early stage then, one deals with the biologic animal rather than, as so frequently happens later, with the pathological animal. In the face of this statement one approaches the mortality records with a feeling of unbelief, with wonderment and with shock. One-fourth of all deaths in the large cities of the world are of persons under one year of age! The knowledge that the baby, whose expectation of life should be the best, has a poorer chance at birth than a person seventy years of age is a just cause for alarm.

In the District of Columbia the infant death rate, though high, has been improving each year. In 1906 there were 6,529 births and, for the same period, 1,233 deaths in infants under one year of age. This means 188.8 deaths during the first year of life for every 1,000 births. (For 1900 there were 281 per 1,000 births.) Of these deaths 429, or one-third, were directly due to causes, like malformations and contagious diseases, other than intestinal disturbances. Regarding deaths from diarrhoeal diseases the accompanying table (Table I) will show the conditions in Washington for the last twenty-five years:

Table I.

Death rate from Diarrhoeal Diseases for Children Under 2 Years of Age per 100,000 People per Annum.

1880-1884	162
1885-1889	168
1890-1894	175
1895-1899	135
1900-1904	109
1905	104
1906	97

From 1880 to 1895 the death rate from diarrhoeal diseases per 100,000 people per annum for children under two years of age was about 170. In 1895 it was 135, and has decreased each year until in 1906 it was 97. The only explanation of this sudden lessened mortality from intestinal disturbances in infants in 1895, after fifteen years of even high mortality, is a law passed March 2, 1895, "regulating the sale of milk in the District of Columbia and the establishment of dairy and dairy farm inspection under the provisions of that law." (Woodward).

In 1900, when Washington had an infant mortality of 281 deaths during the first year per 1,000 births, Charleston, S. C., had the highest rate of 419.5 per 1,000 births. At the same time the States, as would be expected, showed a lower death rate. Of the few States where vital statistics are recorded, Rhode Islands stood highest with 197.9, and Michigan lowest with 121.1 per 1,000 births. But nearly ten years have elapsed and all these towns and States have doubtless made as big strides as Washington in lessening the infant death rate.

In foreign countries the conditions seem as bad as with us, and in some places, worse. In Berlin the record for five years (1900-1904) averaged 207.8 deaths under one year per 1,000 births. Prausnitz (Pfaunder and Schlossman) represented in a graphic manner all deaths in Germany during one decade (1871-1880) per 1,000 people. His chart shows a very rapid decrease in the mortality from birth to two years of age, followed by a more gradual decrease to fifteen years of age. From the fifteenth year the chances for death increase slowly but continuously. The Germans have a wealth of statistics in regard

not only to the causes but to the circumstances of death. Their death returns of infants show whether the child was breast fed or artificially fed. In Berlin (Harrington) the average for deaths of breast-fed babies to all deaths of babies in 1900-1904 was 9.7 per cent (less than one tenth.). Of 65,720 deaths reported by Boeckh* (Abbott) the number seems to be even smaller, as shown in the accompanying table

Table II.

Food	Deaths	Births
Mother's milk	7.4	per 1,000
Mother's and cow's milk......	21.4	" "
Cow's milk only	42.1	" "
Milk substitutes	67.7	" "
Cow's milk and milk substitutes.	125.7	" "

In France conditions have been similar (Planchon). Of 2,840 deaths during the first year of life, 1,362, or 47.9 per cent were due to intestinal disorders. Of these of intestinal origin only 9.9 per cent (136) were breast-fed. This shows a remarkable prevalence of diarrhea among the bottle-fed babies. In the agitation in France to save citizens, factories post placards stating the advantage of breast feeding and provide special rooms for this purpose. In some parts of Italy there is a law requiring such a room in factories where more than fifty women are employed.

It would seem then, from the excessive mortality among infants, that steps should be taken to decrease this death rate as far as possible. Much has been done, as will be shown later, but there is yet the most to do. Nor has there been a great deal of difficulty, in late years, in placing the blame. It is not that the cause of the high mortality eliminates only the weak, for it is well known that those communities with the highest infant mortality have also the highest mortality for children from one to five years of age. It is not among breast-fed babies, for the mortality among them is shown to be very small in several countries, and what will hold in those parts in this particular, will hold approximately in our own cities. It is not to be accounted for entirely by hot weather and crowding and inherent defects. All the difficulties that have been experienced have not been due to the inability of the physician to modify the milk satisfactorily, however difficult that may have been at times. But it is due, in otherwise simple feeding cases, to intestinal troubles developing often in healthy babies fed on dirty milk. The best substitute food practically is cow's milk, and for such a purpose it must be used. The only conclusion is that cow's milk must be either pure or purified. It is for the purpose of studying this side of the question, more than any other, that milk commissions have been formed and have labored, that milk committees have become important in the medical societies, and that a general

* International Statistical Bulletin, Von II, No. 2, p. 14.

crusade has been started against dirty milk. It is partly, too, for that purpose that this report has been written, and the subject certainly can not be avoided later in this chapter.

Physiology of Mother's Milk.

The question of feeding a baby has ever been made prominent. The helplessness of the infant and the necessity of caring for it have been enhanced by the difficulties attending the proper digestion and assimilation of its food. A study of the principles underlying this proper assimilation may be considered profitably at this point. The natural food of any new-born mammal is its mother's milk. These different mothers have in their milks the same elements, namely, fat, sugar, proteid, mineral salts, and water. They appear in different proportions in different animals, as may be seen from the accompanying table

Table III.

	Fat	Sugar	Proteid	Mineral Salts	Water
Cow	4.00	4.50	3.60	.65	87.25
Goat	4.10	4.45	3.70	.85	86.90
Woman	4.00	7.00	1.50	.20	87.30
Mare	1.10	6.65	1.90	.30	90.05
Ass	1.30	6.30	2.10	.30	90.00

They also vary greatly in the same animal, and this table represents only a good average for each. These elements, which are supplied for the individual baby after birth, must be properly digested before their products can be taken into the blood for building up the different tissues. Certain substances are found in the digestive tract to do this work. Besides the organized ferments like yeast and bacteria, there are present in the digestive tract certain unorganized ferments called enzymes. Each enzyme has a distinct, a specific work, to do. There are

- a proteolytic enzyme (example, pepsin) for splitting proteids,
- an amylolytic enzyme (example, ptyalin) for splitting starch.
- a lipolytic enzyme (example, lipase) for splitting fats,
- a sugar splitting enzyme,
- a coagulating enzyme (example, rennin) for coagulating or clotting, and an oxidizing enzyme.

Each of these is found in the infant and is ready to function at birth, except possibly the amylolytic enzyme. As a result, when the slightly alkaline mother's milk enters the infant's stomach no change takes place immediately because the rennin, which soon coagulates the casein into a fine flocculent curd, can not act until hydrochloric acid is secreted. The act of eating stimulates the secretion of the acid. Sufficient is secreted by the end of two hours to have completed the coagulation and some is left, so that there is free hydrochloric acid

in the stomach. The coagulum is then digested in part by the pepsin. There is no action in the stomach on fats, sugars, or starches. As the enzymes which act on them are in the intestine, (except ptyalin in the saliva) the greater part of digestion is carried on in the duodenum. If the stomach is too alkaline the food will be carried into the intestines before peptic digestion can take place. If there is too much fat present it surrounds the particles of the coagulum and the proteolytic enzyme can not reach the casein. So it is seen that each element must be taken in the food in sufficient quantities to develop the proper use of these enzymes but must not interfere with the proper chemical and mechanical workings of digestion generally or there will follow conditions varying from acute intestinal disorders to very slowly progressing general diseases.

The amount of food an adult should take must be sufficient to repair the waste to the tissues and sustain the normal temperature. But in babies the metabolic equilibrium must be more than sustained, since there is continuous necessity for increased size and the repair therefore must exceed the waste. Each element of food has the power to do this to a different degree, depending on the amount of energy it can produce. A standard has been adopted and called a calorie. This (large calorie) is the quantity of heat necessary to raise 1 kilogram of water 1°C. in temperature. The amount of energy or number of calories of each element has been calculated by burning it in a calorimeter and the result has shown that

1 gm. of fat yields 9.3 calories
1 gm. of sugar yields 4.1 calories
1 gm. of proteid yields 4.1 calories

Then a litre of mother's milk, if it contains 4% fat, 7% sugar, and 1.50% proteid will yield 372 calories in fat, 287 calories in sugar, and 61.5 calories in proteid, or a total of 720.5 calories.

These physiological conditions are the bases for many of the various views held by pediatrists the world over.

Mother's Milk.

No food is so good for a baby as that which nature intended for it,—the mother's milk. The importance of this can not be too much emphasized. It is better digested and better absorbed than any other food devised. Nearly every mother should be able to nurse her child. Mme. Dluski holds that 99% of mothers can nurse their children. Cases are seen frequently where, with only a small amount of milk secreted, there might be some temptation to take the baby off the breast, whereas later the supply increased quite sufficiently. In the school of midwifery in Stuttgart in 1882 Herdegen found 23% of women were able to nurse their children; in the same institution in 1904 Martin found nearly 100% were able to nurse (Camerer in Pfaundler and Schlossman). This suggests some discrepancy in the statistics, but it certainly seems that more insistence on the part of

the physician can do much to lessen the number of babies taken from the breast. There is no doubt that babies are taken from the breast with insufficient reason. Much can be done toward modifying the breast milk from a poor food or rich unhealthful food to a normal state. If an examination is made to find the fat percentage and proteid percentage, adjusting the diet and exercise to suit the conditions found will frequently give most satisfactory results.

The best practical fat test for woman's milk, where the quantity is so limited, is the Leffman and Beam modification of the Babcock test.* The requirements for the fat test are (1) a centrifugal apparatus, (2) two small bottles like the Babcock test bottles (but with about one-sixth the capacity) with 100 markings on the neck, (3) two pipettes marked at 2.92 cc. exactly, (4) a small pipette graduated in one-tenth c.c., (5) C. P. sulphuric acid, sp. gr. 1.84, (6) concentrated hydrochloric acid, and (7) fusel oil. With one pipette put 2.92 c.c. of mother's milk into the bottle, tipping the bottle and allowing the milk to flow carefully down one side of the neck. With the other pipette, and even more carefully and slowly, allow 2.92 c.c. of pure sulphuric acid to flow in on top of the milk. Mix slowly and thoroughly. With the small graduated pipette add 0.6 c.c. of equal parts hydrochloric acid and fusel oil. If this does not reach to 5 (the top mark of the scale on the neck of the bottle) add sulphuric acid and water, equal parts, sufficient to bring the surface to 5. Stopper the bottle and invert gently several (2-4) times. It is advisable to use the first breast milk in one bottle and the last milk (after nursing) in the other. The average can be obtained from the two, and two bottles have to be used to preserve the balance of the centrifuge. Revolve specimens in centrifuge for five minutes, 100 revolutions of the handle per minute. Upon removing the bottles the fat will be observed in the neck and sharply defined. Read from the lowest edge of the fat to the top of the meniscus at the surface. As each division represents 3-10 of 1% of fat, multiply the number of divisions by .003. For example, if the fat covers 12 divisions, the fat percentage would be $.003 \times 12 = .036 = 3.6\%$.

The Bogg's method for determining the proteid percentage is very simple and requires less than five minutes' work if the phosphotungstic acid solution is previously prepared. It is a modification of the Esbach test for albumen in urine and is very accurate. The requirements are (1) an Esbach tube of the standard pattern reading from 1 to 7 gms. per litre, (2) a 2 c.c. pipette, (3) a 20 c.c. measure, and the following solution:

"Phosphotungstic acid 25 gms: distilled water 125 c.c. After thorough solution is obtained there is added hydrochloric acid (conc.) 25 c.c. diluted with distilled water 100 c.c."

* This and the following proteid test can be done readily in the physician's office.

This solution will be good for months if kept in a dark bottle. The milk should be diluted with water 1:10 (cow's milk should be diluted 1:20). With this diluted milk, fill the Esbach tube up to the mark U, reading from the bottom of the meniscus. Add phosphotungstic acid solution up to the mark R. The tube is corked and slowly inverted 12 times. Set aside for 24 hours, when the percentage can be read directly at the top of the precipitate (if the dilution be 1 in 20, multiply the reading by 2).

If the physician is too busy to do this work there is doubtless in the vicinity some one who has the time and the technic, just as there is some one who can do urinalyses and blood examinations. In the present day, this analysis, with the comparatively simple technic at one's command, should certainly be done, and one has only to read the pages of Rotch, giving his experiences, to be convinced. He gives analyses of breast milk on which babies are not doing well, followed by analyses after the milks have been changed by exercise, diet, et cetera, and the babies doing well. During the interval, it is frequently best to put the baby on a modified cow's milk, pumping the breast at regular intervals to keep up the supply of mother's milk. It must be remembered that although the sugar and proteid are constant in milk taken from a breast at a given feeding, the fat is very low at first (1% to 3%) gradually increasing to the end of nursing to 6% to 8% (Tayler-Jones). The writer has found it at the end as high as 16.8%.

There are reasons, however, for taking the infant off the mother's milk. Engel (Pfaundler and Schlossman) says that the presence of tuberculosis in the mother is the only absolute contraindication. This may be considered as going somewhat to an extreme, but certainly it is not necessary as frequently as was formerly thought. In mastitis for instance if there are no pus cells in the milk the baby should be put to the breast. If there are such it may be that a temporary change only is necessary. In eclampsia, babies have thrived well on mother's milk when at first for a few days other provisions had to be made for them. The menses need not interfere with nursing. When babies are affected at such times, a substitute milk can be given for a few days.

The care of the breasts should begin early in pregnancy. If the nipples are inclined to recede or are not well formed the patient should be instructed how to draw them out daily. For one month before the expected date of confinement a solution of equal parts of water and 95% alcohol, saturated with boracic acid should be applied night and morning to the nipples, which then become less tender and are less readily infected. Before and after nursing a plain boracic acid solution should be used for bathing the nipples, as well as for wiping out the mouth of the infant.

The new born should be placed to the breast as soon as possible after the mother is made clean and comfortable and the baby has been

cleaned* and dressed. The garments should be very plain, only sufficient for warmth and comfort and the baby then taken to the mother for nursing before either goes to sleep. The longer the delay the greater chance there is for the baby losing the instinct of nursing with which it is born. More than one baby has been put on substitute food because, after hours of delay, its instinct for taking the breast has been lost. Water may be given freely during the first three days, before lactation is established, but sweetened water is not advisable and certainly not sweet weak tea, as suggested by Camerer (Pfaunder and Schlossmann). The time and frequency of breast feeding should be somewhat as in the following table:

Age	No. 24 hrs.	Intervals hrs.	Night
First 2 days	5	4	1
3rd day to 4th week	9	2	1
4 to 6 weeks	8	2½	1
6 weeks to 3 months	7	2½	0
3 to 5 months	6	3	0
5 to 12 months	5	3	0

Until lactation is established the nursings should be four hours apart during the day and once at night. The two-hour interval, begun with the establishment of the milk secretion should be changed to 2½ hours before four weeks have passed, and that to three hours before the baby is three months old. As each case has to be considered individually, this should not be done invariably. The night feeding, really essential in the early weeks, should be dispensed with as early as possible, certainly by the fourth month, and preferably earlier. In any case, regularity should be the keynote for feeding, for any other course causes digestive irregularities, beside changing the milk considerably. It is immaterial whether one breast or both breasts are used each time, but it is important that the first breast should be well drained first, as this emptying of the breast tends to give a better milk supply. The nursing should take place very slowly; if the breast milk flows rapidly, the baby should be drawn away from the nipple every few seconds during the first part of nursing. Colic is more likely to be due to too rapid taking of the milk than to any food that the mother has eaten. Her diet has been blamed for far too many troubles of the nursling in the past. Weaning should take place before the end of the first year, depending somewhat upon the relation of summer to that age. In northern climate it is usually better to nurse through the summer months. All children by the eighth month should

* For the first three days of life, instead of soap and water the baby should be cleansed with a warm, pure sweet oil, preferably olive oil, sufficient being left on the skin to be sensible to the touch. This is not so exhausting as the soap and water bath, keeps a more even temperature, preserves the delicate skin much better, and cleanses thoroughly, except perhaps the hair, on which soap and water may have to be used.

begin to have some other foods prescribed by a physician. As early as the third or fourth month one bottle feeding may be substituted for a breast feeding in order that the mother may have rest or recreation away from the baby.

Wet Nurse.

If the mother can not nurse her child, the next best method of feeding is from the wet nurse. The choosing of a wet nurse is a responsibility which should be undertaken only by the physician. She should be free from tuberculosis and syphilis, but aside from this, the condition of her own child is the most important consideration. It can never be told, from the appearance of a breast, whether the supply is sufficient or not. This can only be judged by her own child and can only be decided by trial. For a young baby the milk should be free from colostrum and should not be more than six or seven months old. I can not agree with Parish that her moral character, aside from her responsibility in dealing with the baby and the household, is of importance, for no detrimental influences can come to the baby through her milk. If she has been used to house work,—and usually she has—she should be given plenty of it to do, for a change to an idle life and rich food will so alter the milk that it will be of little value. It is often advisable to continue her own child on the breast, for a woman who ordinarily gives 1 to 1½ quarts of milk a day will, with use, increase the amount to 3 or 4 quarts. And to take her own baby off the breast is defeating the end which is so vigorously advocated. The physician's responsibility to the wet nurse is also to be considered. The child that is given to her to nurse must be free from syphilitic taint and it is a grave question whether any use should be made of a wet nurse in foundling asylums.

Cow's Milks .A Comparison.

The substitution of some food other than human milk for a baby is a serious matter. The fact that there is such a diversity of views as to how this substitution shall be conducted is a recognition of inability as yet to understand fully the problems involved. It is fairly uniformly conceded, however, that cow's milk is the best and most practicable substitute in most civilized countries.*

* Asses' milk undoubtedly would be a very satisfactory milk could it be obtained, because the proteid forms a jelly-like mass in the stomach rather than a curd mass. Goat's milk is especially good because the goat is a more sturdy animal than the cow and the milk, therefore, less liable to be affected by disease and disposition.

The average compositions in woman's milk and cow's milk are as follows:

	Woman's	Cow's
Fat	4.00	4.00
Sugar	7.00	4.50
Proteid	1.50	3.50
Mineral Salts	.20	.75
Water	87.30	87.25

It would seem that, by using water to dilute the proteid of cow's milk, by adding milk sugar to increase the total sugar, and cream to bring the diluted milk back to a 4% fat, one would get practically woman's milk, in other words, change from a 4.-4.50-3.50 to a 4.-7.-1.50 milk. Practically and theoretically both in the stomach and in the test-tube they are not the same and the following table will show some of the reasons for differences:

	Woman's Milk	Cow's Milk.
Fat	3% to 5 %. Finer emulsion. More oleic acid. Twice as many fat globules as in equally fat cow's milk. Thus more digestible.	3% to 5%. More volatile acids. More difficult to digest.
Sugar	7%	4.5%
Proteid	1.50%. Less casein. More lactalbumin. Forms fine curd.	3.50%. More casein. Less lactalbumin. Forms large curd. More difficult to digest.
Minerals	More nuclein. More lecithin. More organic phosphorus.	More total phosphorus but more inorganic than in human milk.
Reaction	Slightly alkaline.	Amphoteric—or acid, according to the diet of the cow.
Bacteria	Few:—theoretically sterile, and as it is ingested at once is practically so	Many bacteria at once unless the most painstaking precautions are used. In much marketable milk billions of bacteria.
Ferments	Characteristics of human milk.	Characteristics of cow's milk and not characteristic of human milk.

There are other difficulties beside these chemical, physical and bacteriological differences already mentioned. The question of infection arises—from tuberculosis in the cattle or in man handling the milk; typhoid fever and the exanthemata from employees. There are fermentative and putrefactive changes. Improper feeding of the cattle may be very evident in the milk and ill treatment is sure to be ap-

parent, for the cow is a tender and delicate animal. Yet, given all these things satisfactorily, there is a difference which shows that the milk of each species of animal is adapted specifically to the young of that species.

Review of Methods.

It can readily be understood that with all these difficulties facing the profession new methods have been continually adopted and discarded for other new methods and that at present there is a wide diversity of opinion regarding proper substitute food for an infant. Since this is the case and since such different views are held by the most eminent physicians in this line of work, it seems advisable to outline the developments of the feeding problem in the last quarter of a century. As far back as 1861 Gerhardt in Germany said that by the addition of water and sugar to cow's milk it could be made like mother's milk, although he held that mother's milk was composed of a 2.6 fat, 4.3 sugar, 3.9 proteid. Biedert in 1874 advocated adding water and sugar to cream. Yet he said that there was 4% of casein in mother's milk, though sometimes only 2% to 2.5%. From his researches he emphasized two points, that the casein in mother's and cow's milk were different physically and chemically, and that the amount in the two milks was different. His principal prescription was

> Cream (composed of 9.5-3.4.) ⅛ litre; previously boiled water, ⅜ litre; milk sugar, 5 gms. (making total of 15 gms.)

The result he gave as a 2.4-3.6-1 mixture. He had six different formulæ: the highest fat in any one of them was 3%, the highest sugar 4%, and the highest proteid 3.2%. That was in 1874.

In 1882 Dr. A. V. Meigs, of Philadelphia, presented a rational basis for modifying milk. He said that human milk, from careful analyses, contained only 1% of proteid and that cow's milk, therefore, to be proper food for a baby, should be sufficiently diluted to lessen the proteid to 1%. This, whether applied in the future or not, may be looked upon as the first scientific step toward solving a very difficult problem.

Meigs continued his researches and insisted that his results of low proteid and high sugar were correct and that those of Vernois and Becquerel, so much quoted, of casein 3.92% and sugar 4.36% in woman's milk were wrong. He judged that they, in separating the sugar from the proteid, did not get the former all out. Any one who has attempted to do this bit of physiological chemistry with human milk knows that such might readily happen. Two points he maintained stoutly, (1) that whatever differences there are in the two caseins (woman's and cow's), the quantity of woman's is one-third that of cow's and (2) that modifying cow's milk to give the percentages of woman's milk, (as his analysis found it, 4.2-7.4-1) one should get a prescription that would serve from the time of birth until eight months of age. Though he claims no originality in modifying milk,

he does claim that copying nature had not been done previously because no one knew what was the proteid percentage of woman's milk. His prescription was

Cream	2 parts
Milk	1 part
Lime water	2 parts
Solution of milk sugar	3 parts

2 to 3 oz. q.2h.

As cream was usually old, he advised in 1889, when discussing the subject, that top milk be obtained by letting it rise in tall pitchers. The solution of milk sugar was made by adding 17¾ drams to a pint of water. In this same paper he says that sterilization of milk is not necessary in all cases, but is most necessary among the poor. Booker, in the discussion, advised sterilizing in summer. Holt called attention, in the light of our present knowledge, to an interesting condition. He said that frequently the mistake has been made of giving too much and too frequently of artificial food, and that he had been examining the size of stomachs, with a view to finding out the proper amount of a feeding.

It was soon apparent that the one formula was not practicable because of the different weights and conditions of children, and that the same food for a child of eight days and one of eight months was quite impossible. A more flexible system, adapted to the ability of the child, was worked out. This came to be known as the percentage method of feeding, or, on the other side of the water, as the American method. To no one so much as to Dr. T. M. Rotch, of Boston, is the world indebted for the development of this method and the working out of the principles involved. The difficulties were innumerable, and at times seemed insurmountable, but the results will remain as a monument to the father of percentage feeding. His idea very early came to be that, as skilled pharmacists prepared drugs, so should milk laboratories be established where educated clerks, under medical supervision, should fill prescriptions for milk modified to exact percentages. This must have seemed impossible to nearly every physician at that time, yet in 1891 the first Walker-Gordon laboratory, under the care of Mr. G. E. Gordon, was established in Boston. One year later a second was established in New York City, and today there are 21 laboratories* in as many different cities (Rotch, Morse). At these laboratories all cases for modified milk have to be on the prescription of a physician. The advantages of this method were innumerable, both to the mother and the physician. It also placed infant feeding where it should be,—under the physician's care. The two objections to it were expense, costing about 40 cents a day, and the

* The laboratories have distributing stations at all the principal resorts from Bar Harbor to Norfolk. On their 69 different farms there are more than 4,000 cows, all tuberculin tested.

manipulation necessary. But if manipulation had to be, it was better done with the best of facilities for cleanliness and exactness than in untrained hands. In difficult feeding cases the results were found to be much more satisfactory than in any other way, for variations from the formula called for were at a minimum and changes of such a small percentage as would be impossible in home modification could be made.

If expense made the laboratory milk impossible to consider, milk could be modified at home less accurately but, in most cases, quite satisfactorily. There were many questions which arose regarding the creams, sugars, et cetera, to be used. Cream, as is well known, may be obtained either by gravity or by centrifugalization. Certain objections had been raised against centrifugal cream, but of the two it seemed much preferable because freshness was considered a very important quality and gravity cream was 24 hours older. As top milk has been coming into use more and more for home modification, this agitation over centrifugalized versus gravity cream will drop into the background to some extent. Milk sugar and cane sugar each had its advocates. Holt, Rotch and Morse believed in the former as more rational, because the sugar in woman's and cow's milk was milk sugar, and because cane sugar fermented sooner. Jacobi was one who for years advocated cane sugar instead of milk sugar, because milk sugar hastened lactic acid fermentation and so caused quicker coagulation with larger curds. In addition it changed into oxalic acid (Baldwin) by fermentation in the intestinal canal. A further difficulty with the use of milk sugar was its impurity. Proteid, in percentage feeding, has seemed, in the past, to cause the most concern. To reduce the proteid, or at least the curd formed from it, several methods have been used. The simplest method was to lessen the proteid by dilution; a second was to lessen the casein by adding whey to a smaller amount of cream or milk, making the proportion of casein and whey more like that in mother's milk (see p. 283); a third was partly to peptonize or digest by adding pepsin or pancreatin (see p. 284); a fourth, by the use of a cereal diluent to break up the curds (see p. 287). The first method has been adopted in routine for a long time. For instance, if there had been given a 2.-5.50-2. and it was decided that the proteid was too high and that a 2.-5.50-1.75 should be used, the change could readily be made. It has been necessary to have either a tabulated card* showing amounts of cream, milk, water, and sugar to be used or, which is even more satisfactory, to have formulae in which, by substitution, one may readily obtain the proper number of ounces of each (see p. 292).

With a formula, one can use the principle of percentage feeding without, at the same time, using the high fat percentage which has been advocated so much in the past. Holt and others have for several

* Such tabulated cards have been gotten out, one by Dr. Ladd of Boston, and one by Dr. Westcott, of Philadelphia.

years advocated lower fat and higher proteid modifications and the results justify the change.

Rotch has said that to use modified milk without knowing the percentages was like running a ship without a compass. This is so true, and the satisfaction that comes of knowing them well repays one for figuring it out. In the end it is really a simpler method. It is much more intelligible to have a physician state that he is using a 2.-5.50-0.75 with eight feedings of 3 ounces each than to say he is using 2½ ounces of a 16% cream, 2 ounces of skim milk and 1 ounce of milk sugar in a 24-ounce mixture. One has, in the former, a basis on which to compare it with other cases; one has a compass as guide.

Whey mixtures.—Proteid in milks is composed principally of casein and lactalbumin (curds and whey) in proportions as follows (König):

	Casein	Lactalbumin	Proportion
Woman's	0.59	1.23	1:2
Cow's	3.02	0.53	6:1

This gives approximately a proportion of 1:2 in woman's milk and 6:1 in cow's milk. There is much more casein to coagulate in cow's milk, in proportion, and whey* has been added to milk mixtures to make the proportion of casein and lactalbumin like that in woman's milk, 1:2. Whey mixtures have been used for very young infants—premature or during the early days of life—in acute indigestion cases, and in certain other feeding cases. As the casein had to be reduced to a minimum, a small amount of rich cream had to be used with whey as part or all of the diluent. For exact directions see Rotch. The whey should be heated to 150°F. to destroy the rennet ferment before the addition of the cream which would otherwise be coagulated.

Alkalinity.—Since human milk is alkaline, it has been supposed that, to make cow's milk as much like human milk as possible, something should be added to cause a slight alkalinity. The majority of writers in this country have used in the past, and indeed many of them are today using, lime water* for this purpose. Jacobi has never advocated any alkaline addition: he does not approve of lime water and makes a strong protest against bicarbonate of soda. The idea seemed to be to delay coagulation in order to make the curd finer. On the other hand, it may delay coagulation until the food is carried on into the intestine, thus preventing peptic digestion and acting adversely

* To make whey: Into a clean saucepan put 1 pint of fat-free milk. Heat to 100°F. and add 2 teaspoonfuls of essence of pepsin, liquid rennet or a junket tablet; stir sufficiently to mix. Allow to stand until firmly coagulated. Break up with a fork and strain. The whey (liquid part) is ready for use. Keep cool.

* To make lime water: Place a piece of unslaked lime the size of an egg in a gallon of water in an earthen jar or glass bottle. Stir and let settle. Pour off this first water and add fresh. Use from this. Replenish by adding water.

on intestinal digestion because chyme coming from the stomach under this condition is alkaline instead of acid. This danger is of course at a minimum but it is a question (White) if the curd is made finer by adding the lime water.

Peptonized milk.—A partial digestion of the proteids of milk in order to relieve the stomach of some or most of its work has seemed necessary in some cases. It has been used in acute indigestion and in chronic cases where some relief from work has been necessary for the stomach. It should be used very discreetly and should not be used for any length of time. The method of making it is as follows:

Milk 1 pint.
Water 4 oz.
Bicarbonate of soda 15 gr.
Extractum pancreatis 5 gr.

To peptonize partially, heat to 105°-115°F. for ten minutes and place on ice until used, for the cold will check the digestive process. To peptonize completely, heat for two hours, but as this is very bitter, it is not often used.

Sodium citrate.—Wright in 1893 suggested the addition of sodium citrate to cow's milk to make it a "humanized milk" so far as the lime salts were concerned. His argument was that (1) rennet coagulation is less firm if some of the lime salts become precipitated as insoluble salts, (2) since human milk contains 0.03% lime salts and cow's milk 0.17%, much of that in cow's milk should be made insoluble, (3) sodium citrate added to plain milk will do this. He advocated its use especially in the treatment of dyspeptic conditions. Though not extensively followed, it has been used in healthy as well as in sick infants.

Diluents.—The most common diluent for modifying milk is boiled water. There are many, however, who believe that a cereal diluent should be used even in very young babies because the starch acts on the proteid—probably mechanically—prevents a hard coagulum and thus aids digestion. Jacobi has held this view for more than 40 years. On the other hand, there are those who hold that as woman's milk does not contain starch, it should not be used during the first 10 to 12 months. It can undoubtedly be used to advantage in many cases after the fifth month. Methods for making the gruel or water are as follows:

Barley water.—Make 2 tablespoons of barley flour into a thin paste, stir in 1 quart of water. Boil 15-20 minutes. Strain. This is used in acute conditions in place of water when milk must be omitted.

Rice water.—Make as barley water, using 2 tablespoons of rice flour instead. Or use rice, cooking slowly and adding continually up to 1 quart. This is useful in diarrhoeas.

Oatmeal water.—Stir 2 tablespoons of oatmeal into 1 quart of boiling water. Cover and allow to simmer for 2 hours. Replace the water as it evaporates. Strain. Useful in constipation.

Dextrinized Gruel.—Chapin advocates dextrinated gruel, believing in many cases that its action as a diluent is more satisfactory than the simple gruel or water, because the sugar can be digested by the infant better than the starch and the action of breaking up the curd is just as satisfactory. He makes it by adding to the gruel already cooked and cooled, but not strained, 1 teaspoonful of disastase solution. Stir and strain. The disadvantage in this is that there is no chance for developing the amylolytic digestive functions, as there is in using simple gruels.

Butter milk or acidified milk.—Butter milk has been used in Holland for infant feeding for about a century and a half, and was popularized first by the peasants. From Holland its use has spread to many other countries as a food for infants. It is composed of a 0.50 fat, 3.0 sugar, 2.50 proteid, or about that, and as a food, therefore, supports the theory of calories. It contains .34% of lactic acid. It is probably more useful in cases requiring a low fat percentage and high proteid percentage in a very readily digested form. Baginsky considers it a specific in dyspepsia. It is not ordinarily used raw but cooked with sugar and flour (see Morse).

In foreign countries the percentage method has been used only to a small extent. In England it has been advocated quite a bit but hardly at all in France. They have been using simple dilutions and strong ones, as much as plain milk and water equal parts, for a baby of two weeks. Budin prefers whole milk sterilized, but small quantities with few feedings. In Germany the dilution of half each is not reached until the baby is about two months old (Camerer). In Germany they have had also a milk modified by what is known as the Gärtner process.* Its use in this country has never been advocated.

Another method, inaugurated by Heubner and which has a large following, especially in Germany, is a milk based on the number of calories a baby should receive in 24 hours. Some time previously Biedert advocated the smallest amount of food necessary for normal increase in weight, but Heubner determined the number of calories per day per kilogram of body weight a breast-fed baby should get in order to develop properly. This energy quotient he found was about 100 calories for from three weeks of age to six months, and from six months a gradual decrease to about 85 calories at the end of the first year. The overfeeding which had existed previously could be pre-

* This is as follows: Dilute milk at cow heat (36°C.) with an equal quantity of warm boiled water; pass the mixture through a centrifuge, so adjusted that the tubes for the cream and skim milk carry off equal quantities. The cream is the modified milk and contains 3-2.50-1.70 and so requires about 5% of sugar added. Of course the fat varies with the fat percentage of the natural milk.

vented in this way. This was especially brought out by Czerney and Keller. They showed that the difficulty in ordinary feeding was not the proteid, which is readily digested, but the excess of fat. As a result they have gone somewhat to the other extreme and advocated fat-free milk. Just why an infant born with a lipolytic ferment for splitting fats in its duodenum should be given a food entirely free of that element is hard to be understood. That very little fat can be digested by certain babies is, however, readily recognized.

The opinions seem to be, after twenty-five years, more diverse than they have been at any time during that period. The effort to modify cow's milk to make it like human milk has not always, even in the best hands, been successful. The adding milk sugar and decreasing the proteids, adding whey and adding lime water,—the reason for each carefully and scientifically worked out,—has not met the requirements of many cases. In other words, the simple chemical fulfilment without the physiological does not make cow's like human milk. This has undoubtedly been emphasized in great part by a too high fat percentage and, therefore, by a too high energy quotient. The other extreme of fat-free milk (probably a 0.50% fat), though most valuable in many cases, can not be advocated as a routine diet. The problems are still before us; probably the only way to do at present is to have an understanding of all the theories, know something of the practices, study the baby as an individual and apply as the study of the case indicates. Above all it must be remembered that babies can not be fed by rule.

The Simple Feeding Case.

For some time the writer has been using very simple formulæ for the average feeding case. The first essential is good fresh milk from a mixed herd of tuberculin tested cattle, preferably from the more robust breeds of Holstein, Durham, and Ayrshire. The milk should be of the class called certified milk, if such can be obtained. The three most important essentials are sterilized vessels, including the milking pail, bottling on the farm and a low temperature (40° F.) from immediately after milking until delivery to the consumer. If poor or unknown milk must be used it should be pasteurized at 60° C. (140° F.) for 20 minutes (Rosenau). In the heated summer months most milk should be pasteurized at 60° C. for 20 minutes. With fairly good milk the best time for pasteurizing is immediately before using, unknown milk earlier in order that toxins may not develop. Certified milk ought never to need pasteurization.

The utensils and other things necessary for modifying milk are:

Chapin cream dipper (when needed).
A pitcher for mixing.
An 8-oz. glass graduate.
A funnel.
Feeding bottles.

Rubber nipples.
Bottle brushes.
Pasteurizer (or double boiler).
Sterilizer nonabsorbent cotton.
Boracic acid.
Milk sugar or cane sugar.
Lime water (when needed).
Boiled and boiling water.
Bottle of milk.

Utensils used should all be washed well, rinsed well, and then scalded and drained but not wiped. None of these things should be used for other purposes. If cream is to be removed from the top, the first dipperful (this holds ½ oz.) will have to be taken off with a spoon; the rest can be removed by the dipper. The nipples must be simple and the kind that can be readily turned for cleaning.

The plain milk of 4. fat, 4.50 sugar, 3.60 proteid is used ordinarily. By division into eighths and using some eighths of milk and the rest of the eighths water (adding sugar to give the desired sugar percentage) there results a simple and practical method, with known percentages and one that is satisfactory in the average simple feeding case. For example, one-eighth milk gives fat .50 and proteid .45, so that one-eighth of plain milk in seven-eighths water, previously boiled, gives a very weak formula. It is wise, however, to begin on a low percentage formula, for the ultimate progress is then more assured. A three-eighths milk and five-eighths water results in a 1.50 fat and 1.35 proteid, which with eight teaspoons (1 oz.) of sugar to the 20 oz. mixture, gives about a 5.50% sugar. The resulting modification is a 1.50-5.50-1.35. The necessity of keeping the percentages in mind must be emphasized for this is the only satisfactory way to work intelligently on substitute milk feeding. Not only the age and weight, but the vigor of the child, must be considered when deciding what strength should be used, but by two months most babies may safely be put on a 2% fat-1.80% proteid diet (½ plain milk and ½ water). The fat percentage may have to be lowered and this can readily be done by removing top milk before the milk to be used is mixed. An addition of 1 oz. of milk sugar to a 20-oz. mixture adds approximately 4% of sugar. The frequency and number of the feedings should be the same as in breast feeding (see p. 280). The amount at two months should be about 3 or more ounces for the average child of average size; at six months about 6 oz. or less; and at eight or nine months about 7 oz. This should depend, not only on the size and weight of the baby, but cognizance of the number of calories in the 24-hour mixture should be taken into account.

Taking a 2.-6.-1.80 mixture with eight feedings of 3 oz. each for a two-months-old baby weighing 10 lbs., the following results in calories are obtained:

2 % fat	$\times 9.3 = 183$ cal.	$8 \times 3 = 24$ oz. $= 768$cc or gms.
6% sugar	$\times 4.1 = 246$ cal.	10 lbs. $= 4539.9$ gms. wt.
1.8% proteid	$\times 4.1 = 73.8$ cal.	

502.8 calories per 1000 gms. of feeding which is the same as 385 calories per 768 gms. of feeding (the amount of feeding used for this baby); 385 calories for a baby weighing 4539.9 gms. is the same as 85.5 calories per 1000 gms. wt.

As, according to Heubner, 100 calories per kilogram per 24 hours may be allowed during the first three months, it is seen that a 2.-6.-1.80 mixture of 25 oz., making only 85 calories for a 10-lb. baby, may be increased, either in strength, in number of feedings, or in amount in each feeding. The individual case must be the guide. That the calorie value is the only point at issue certainly can not be recognized as true, though as an adjunct to percentage feeding it should be of the greatest assistance. In each one of my feeding cases I know the calorie value and consider it an excellent guard in modifying milk. It is also of assistance in deciding when to increase a baby's food, for it is not desirable to increase the food if the baby is gaining, but, on the other hand, one does not wish to wait for a loss in weight before learning that it is time to increase the diet.

More Difficult Cases.

There are several indications for changing a baby's food. If there is colic the food should be given more slowly, perhaps less of it, and the stools watched. If there is much fat in the stools, the fat percentage should be decreased. Vomiting immediately after feeding suggests a necessity of decreasing the amount of food; if sour masses come up it may be due to one of several causes, such as too acid a food or too fat a food (see p. 278). If the regurgitation comes an hour and a half to two hours after feeding, it may be necessary to help the digestion by peptonizing the food (see p. 287) or the aid may come in one of several ways. At any rate it is a case for study and may be looked upon as a difficult feeding case. Each one of these difficult cases is of necessity a study, and, at times, a grave one. With them, the simple method just described of using eighths of a whole milk does not prove satisfactory and here the accurate percentage method comes into play. In cases where changes have to be made in .05% and that only in one element at a time, the Walker-Gordon laboratory is the only salvation. In most difficult cases it is a greater aid to the physician, who can feel surer of the accuracy of the food. Otherwise he must calculate fractions of percentages and keep his method for calculating the formulæ by him. A very careful history of the infant must be obtained in order to decide the nature of the trouble; whether a chronic indigestion, a feeble digestion, or a difficulty that lies wholly in the intestines. One can learn of pitfalls already encountered and avoid them. One may be able to gain some knowledge regarding the element in the food that

was giving the trouble. After all this has been learned and the percentages decided upon for the home modification one must express it in ounces of each ingredient for the benefit of the mother or nurse who is to have the care of the child. There are many ways of figuring it out, for many methods for calculating the amounts have been published. The simplest one I know that is entirely elastic,—and it is truly simple,—is Baner's as follows:

Q=Quantity desired (in ounces).
F=Desired percentage of fat.
S=Desired percentage of sugar.
P=Desired percentage of proteid.
C=Cream.
M=Milk.

$$\text{Cream in oz.} = \frac{Q}{\text{Percentage of fat in cream}-4} \times (F-P)$$

$$\text{Milk in oz.} = \frac{Q \times P}{4} - C$$

$$\text{Water} = Q-(C+M)$$

$$\text{Dry Milk Sugar} = \frac{(S-P) \times Q}{100}$$

To illustrate, take a 1.50-5.50-1.25, 24 oz., using a 16% cream. It may be obtained by substituting these values in the above equations thus:

$$\text{Cream} = \frac{24}{16-4} \times (1.50-1.25) = \tfrac{1}{2} \text{ oz. cream.}$$

$$\text{Milk} = \frac{24 \times 1.25}{4} - \tfrac{1}{2} = 7 \text{ oz. milk.}$$

$$\text{Water} = 24-(\tfrac{1}{2}+7) = 16\tfrac{1}{2} \text{ oz. water.}$$

$$\text{Milk Sugar} = \frac{(5.50-1.25) \times 24}{100} = 1 \text{ oz. milk sugar.}$$

So we have to give to the mother or nurse this formula:

Cream	½	oz.
Milk (fat free)	7	oz.
Water	16½	oz.
Milk Sugar	1	oz.
	24	oz.

Careful instructions should be added as to how much to put in each bottle and how frequently the child should be fed, and if at all during the night. In addition, if this is your first instruction to her, see that she understands about the utensils and the care necessary.

In these difficult cases, where it is not practicable or possible to have a wet-nurse for every feeding, it is worth an effort to get one for one or two feedings a day. This is done on the principle that ferment-like bodies secreted from the human blood through the milk provide these ferments in the infant's blood, and supposedly give a greater bactericidal power to it. At any rate, the bactericidal power is there.

The premature infant presents an especially difficult problem. There are so many side issues of importance. The incubator, which was formerly considered so necessary, has been discarded by many. It has two very striking objections: the difficulty of keeping the temperature at a proper level, and the lack of fresh air. Either is enough to make one feel that pillows, blankets, and hot water bags are preferable. The best method of keeping the temperature of the little one at normal heat is an electric pad. They can be turned on to three different degrees of heat and are admirable. The oiling of a baby, instead of washing, is most important and absorbent cotton should be used in place of a napkin. It is not advisable to use this cotton all over the baby, for in moving their hands the fine, thready pieces are very liable to get in the mouth. Where breast milk can not be obtained even for one or two feedings one has truly a difficult problem. The stomach can usually hold about one-half ounce of a milk modified to a very low percentage. The frequency of feeding has to be a matter of experiment, but usually every one and one-half hours during the day and three to four hours at night suffice. I had one baby (of 2 lbs. 1 oz. weight) who would sometimes go longer without feeding during the night. The kind of milk, whether a whey mixture as advocated by one school, or the other extreme, fat free, plain milk, as advocated by another, must be decided according to the surroundings, the facilities, and the infants.

Pasteurization, Boiling, and Sterilization.

Years ago many physicians found that boiled milk agreed with babies much better than raw milk. It would keep better, too, and not sour so readily. More than forty years ago Jacobi advocated it. Since then there has come to be some understanding of the bacteria that caused the trouble and how boiling (sterilizing, as they called it) helped the difficulty. Since then, too, Pasteur has added to the knowledge of heating to destroy germs and a similar process has come to be known by his name.

Pasteurization of milk is the heating of it to between 60° and 85°C. (140°-185°F.), followed by rapid cooling. This destroys such pathogenic organisms as occur in milk and the rapid cooling, a most essential part of the process, prevents the rapid proliferation of such spore-bearing and other organisms as may be present in the milk and not destroyed by the heat. Boiling is heating to 100°C. (212°F.) and destroys all bacteria that are not spore bearing. Sterilization is

the destruction of all germs and spores of germs. This requires an autoclave or simple boiling on three successive days. The cause for the use of all these methods as applied to milk is due to the excessive growth of bacteria in this medium and the readiness with which they attack it.

Milk as it comes from the gland is supposed to be sterile. This is the exception, however, rather than the rule. Of 25 nursing women Ringel found only 3 of the milks sterile. In 17 he found staphylococcus pyogenes albus, in 2 he found staphylococcus pyogenes aureus, in 1 he found both organisms, and in 2 he found staphylococcus pyogenes albus and streptococcus pyogenes. There were no pathogenic symptoms, but such would hardly be expected since these organisms are found normally in the mouth. In cow's milk, because of the handling, transportation, et cetera, the number of bacteria are counted more by the thousands and millions. When one bacillus, under favorable circumstances for growth, say a temperature of 100°F., in 24 hours becomes 17,000,000 it is not to be wondered at that milk has done much harm. If milk containing 3,000 germs per cubic centimeter be kept (Chapin):

(1) 24 hours at a temperature of 86°F. it will contain. . . 1,400,000
(2) 24 hours at a temperature of 60°F. it will contain. . . 800,000
(3) 24 hours at a temperature of 42°F. it will contain. . . 2,600
(4) 48 hours at a temperature of 42°F. it will contain. . . 3,600
(5) 96 hours at a temperature of 42°F. it will contain. . . 500,000

This suggests that wonders may be wrought by cleanliness, properly applied, and refrigeration. There are also the pathogenic organisms to be considered. Innumerable epidemics have been traced to the milk supply (Swithinbank & Newman), (Trask).

In considering the raw and pasteurized product, boiled and sterilized milk will not be touched upon. There are several reasons why pasteurized milk is advocated by some authorities. This process destroys all pathogenic organisms, it destroys the greater number of the many other bacteria present and, as a result, it has lessened the mortality from gastro-intestinal diseases among children. These are all good reasons and any one of them is sufficient to convince one of the necessity of heating if these difficulties enumerated could not be eliminated as a part of the milk and if there were no objections to pasteurized milk. Pathogenic organisms can be and are kept out of milk and a large bacterial count has been demonstrated as unnecessary if certain precautions are taken. The use of pasteurized milk has been vigorously opposed by most pediatrists, for routine, because of bad effects which they believe they have seen from its use in children under their care. It is accepted that pasteurizing milk causes the destruction of the lactic acid bacteria (thus preventing milk from souring so that old milk remains apparently good longer), it destroys the lecithin, it changes the sugar and partly destroys it, it makes some of the calcium salts become insoluble, it is injurious to certain

ferments and destroys the germicidal property of milk. Whether rickets and scurvy have been caused by heating of milk—as held by many authorities—can not be settled now, but it is true that more cases are found among babies fed on pasteurized milk than on plain milk, and more among those fed on boiled milk than on pasteurized milk (Holt). And it is also true that they recover from these diseases when taken off the pasteurized or boiled milk. In addition, Doane and Price proved conclusively that raw milk fed to calves was more digestible than pasteurized or cooked milk and that cooked milk caused violent scouring in the majority of trials.

It is unquestionably true that poor or unknown milk can do more harm raw than pasteurized and all such should be heated to 60°C. (140°F.) for 20 minutes. Pasteurized milk can do much harm through the carelessness with which it is treated, and as education is necessary it will certainly be best to educate the public in the right way, so that they will demand good milk. In the meantime the bulk of milk in most cities should be pasteurized where it has to be used for infants. But the effort of every baby's family and physician should be to provide for it from that other portion of the milk supply which carries no menace with it in the raw state. Such can be found in every large city even this early in the crusade against poor milk.

Charities and Municicical Control.

The bettered feeding conditions that have been brought about through individuals, charity organizations and municipal interest should at least be mentioned.

Probably no country has a finer record of infant life-saving institutions than America. Such places as the long pier at Chicago, the floating hospital at Boston, the seaside fresh air homes near New York, and the Thomas Wilson Sanatorium near Baltimore, with their fresh air, hygienic surroundings, and feeding under the physician's directions, save many baby lives each year. Dr. Coit, of Newark, N. J., through his effort to have good milk, has done much not only for the infant and the community, but for the physician. Probably no one has done a greater work than Nathan Straus, of New York. It was in 1892 that he discovered the existence of what he called "permitted murder." He believed the large infant mortality due to bad milk and started one milk depot which fed one thousand children. Any physician doing work among the poor could get it. All milk, besides being of the best quality to begin with, is pasteurized and distributed only within twenty-four hours of pasteurization. In all these intervening years the mortality has decreased and the work has grown so tremendously that it must indeed be a great tax financially to even a very large purse. But think of looking forward to having as a monument in one's old age living beings,—thousands of men and women—who otherwise would have died in infancy!

Cities, through the activities of such individuals, are taking an

interest in the milk question and are coming to regulate the sale of this product more and more. There will undoubtedly be a reformation in the next few years and we will see milk universally inspected just as today meat must be approved for interstate trade.

Summary—1. Infant mortality rate is higher than it should be

2. Breast feeding gives so much more satisfactory results in a baby that every effort should be made to keep it on the mother's milk.

3. One breast feeding a day is urgently needed if a substitute food must be used.

4. Modifying cow's milk to get the same percentages of elements as in woman's milk does not give the same result because of chemical and physiological differences in the elements of the two milks.

5. The percentage method of feeding is the most satisfactory because it gives one a basis to work on.

6. The energy quotient is a most important adjunct, not only in giving a modified milk, but in deciding when to increase the food.

7. The law should require milk inspection.

8. In the meantime, poor and unknown milk for babies should be pasteurized at 60°C. for 20 minutes, though every effort should be made to provide an infant with healthful raw milk.

9. In the whole feeding problem the physician has to keep constantly in mind the fact that each baby is a law unto itself. There are certain broad principles not yet completely worked out and classified, but the individual baby can not be fed by rule.

CHAPTER XV.

MILK PRODUCTS IN THEIR RELATION TO HEALTH.

In this chapter no attempt will be made to discuss the technical methods for the manufacture of butter, cheese, condensed milk, milk powder, ice cream, koumiss, kephir and other milk products. The methods of their manufacture belong quite outside the range of a volume on milk inspection. It is believed, however, that a brief account of the relation of these products to human health may be in place in this volume. Milk products may retain some or all of the contaminations which were present in the milk from which they were made. The extent to which these contaminations persist in the final products of milk depends in large part upon the processes which the milk undergoes in manufacture and upon the elements of the milk which go into the composition of the final product.

Standards.

It seems necessary in discussing this matter to refer briefly to the standards and definitions which have been set up for butter, cheese, condensed milk and other products. The standards followed in this connection are those adopted by the U. S. Department of Agriculture in its work of examining food products.

Skim milk is milk from which a part or all of the cream has been removed. It differs from blended milk which may have been skimmed by centrifugal machines and later received a definite and stated percentage of fat. According to the U. S. standard, skim milk should contain not less than 9.25% of milk solids.

Buttermilk is the product that remains when butter is removed from milk or cream as a part of the process of churning. An artificial buttermilk is much used, particularly in the South, and consists for the most part of sour skim milk to which small quantities of whole sour milk have been added, after which the mixture is agitated to give it the appearance of buttermilk. There is nothing about the composition of artificial buttermilk or the method of its preparation which should render it any less wholesome than true buttermilk obtained in the process of churning.

Condensed milk or evaporated milk is milk from which a considerable portion of water has been evaporated. It is impossible to specify in the short definition of condensed milk the percentages of its various constituents for the reason that these vary so greatly in the processes of different manufacturers. The process of evaporation is carried on longer by some manufacturers than others and in some cases a part of the cream is removed while in others this is not the case. Moreover cane sugar may be added to condensed milk to the extent of 40% or

more, which will appear in the analysis in addition to the milk sugar normally present in milk.

Milk fat or butter fat is the fat normally present in milk. The U. S. standard for milk fat requires a Reichert-Meissl number not less than 24 and a specific gravity not less than 0.905 at a temperature of 40 degrees C. The term cream is used to mean that portion of the milk rich in butter fat which rises to the surface of milk on standing or is separated from it by centrifugal force in the operation of machines. Standard cream should contain not less than 18% of milk fat. Evaporated cream is the term used to denote cream from which a considerable proportion of its water has been evaporated.

Butter is the product obtained by gathering in any manner the fat of fresh or ripened milk or cream into a mass and also contains some of the other milk constituents with or without salt and occasionally coloring matter. The U. S. standard for butter requires the presence of 82.5% of butter fat. Renovated or process butter is a product obtained by melting and re-working butter without the use or addition of any chemicals or substances except milk, cream or salt. According to the U. S. standard renovated butter should contain the same amount of fat as standard butter, namely 82.5%.

Cheese is the solid ripened product obtained by coagulating the casein of milk by means of rennet or acid with or without the addition of ripening ferments, seasoning or coloring matter. Whole milk or full cream cheese is prepared from milk from which no portion of the fat has been removed. Skim milk cheese is made from milk from which some of the fat has been removed. Cream cheese is made from milk and ceram or milk containing not less than 6% of fat. According to the U. S. standard whole milk or full cream cheese shall contain in its water-free substance at least 50% of butter fat.

Hygienic Relations.

Cream.—If milk is allowed to stand so that the cream rises to the surface by the gravity separation of the constituents of milk, fat globules collect upon the surface and in rising carry along with them certain amounts of sugar and the salts of milk as well as some of the bacteria with which the milk was contaminated. The cream of infected milk may therefore contain such pathogenic bacteria as are found in the milk from which it was removed and these bacteria retain their virulence in cream practically as long as in milk. According to analyses made by Koenig, cream obtained by gravity separation contains 26% of fat and according to analyses by Veith cream obtained by centrifugal separation contains 50% of fat. The cream offered upon the market ordinarily amounts to about 10% of the volume of the milk but may exceed 20%. The amount of fat required to be present in market cream is regulated by state and municipal laws and varies considerably. As a rule the standard requires about 18% of fat.

Skim milk.—This product is not as extensively sold in this country as in Europe. Wherever skim milk is offered upon the market the legal regulations usually require that it shall be labelled as such and as a rule the requirement of total solids in skim milk is about 9%. The wholesomeness of skim milk obviously depends upon the conditions under which the milk was drawn and the treatment which it subsequently receives. The pathogenic and other bacteria which may have gained entrance to the fresh milk remain in about the same proportion in skim milk and the conditions for their growth and multiplication in skim milk are favorable. If skim milk is to be obtained in a sweet condition it is practically necessary that it be separated by centrifugal machine since the cream will not separate by the gravity method until considerable time has elapsed, usually sufficient to allow the lactic acid bacteria to multiply to the souring point of milk.

Butter.—Numerous investigations have been made to determine the possibility of the growth of pathogenic bacteria in butter and the length of time during which these organisms retain their virulence in butter. It has been shown by Laser that cholera bacilli which have gained entrance to butter may remain virulent for 32 days and typhoid bacilli three or four weeks. If the virus of plague gains entrance to butter it remains in a virulent condition for two months or more if the butter is kept at a relatively low temperature.

Different investigators have determined somewhat different periods for the duration of the virulence of tubercle bacilli in butter. Thus Moore found active tubercle bacilli in butter 90 days old and Gasperini in butter 128 days old. In a number of samples of butter which were examined by the German Imperial Health Office the tubercle bacillus was found in 32% of cases. There is no satisfactory evidence regarding the transmission of tuberculosis to human beings in butter but it must be considered as probable that the disease can be transmitted in this way, especially in view of the fact that tubercle bacilli remain sufficiently virulent in the butter to infect guinea pigs. In an examination of the butter from 36 creameries, Teichert found tubercle bacilli in that from eight of the creameries. The bacilli appeared to lose their virulence after about three weeks. A large number of other organisms were also present in butter, including lactic acid bacteria, yeast and various species of molds.

According to observations by Obermuller, the action of pathogenic bacteria is much intensified by the presence of butter fat. In his examinations a large proportion of butter samples contained tubercle bacilli. In one instance each of 14 samples taken in Berlin contained bacilli of sufficient virulence to kill guinea pigs when inoculated into them. Another species of acid-resistant bacteria often occures in butter and may be mistaken for the tubercle bacillus unless inoculation experiments are made. It appears that the milk of tuberculous cows is not fit for use in the manufacture of butter unless previously

pasteurized and a large number of investigators have recommended this procedure.

It is unnecessary to review in this connection all of the numerous articles which report the examination of butter for tubercle bacilli, the relative virulence of the bacilli in butter and the duration of their virulence. As a general proposition it may be stated that tubercle bacilli are found much less frequently in butter than in milk.

The effect of the feed consumed by the cows upon the appearance, composition and flavor of the butter has been extensively studied. In some instances the disagreeable flavors in butter have been traced directly to the use of unsuitable feed stuffs. This is particularly the case where cows are allowed to consume plants with striking pungent flavors or odors, which persist in the milk and cream.

The firmness of the butter may be greatly modified by the ration fed to the cows. This is a matter which does not concern the wholesomeness of the product, but complaints are sometimes made regarding the soft character of the butter. Bartlett and others have found that gluten meal and gluten feed have the effect of producing a soft butter and should therefore not be used in too large quantities. If feeding stuffs containing a high percentage of oil are given to cows the butter may show the specific effect of these oils. Thus it has been found that cottonseed oil may be readily detected in butter from cows which have eaten large rations of cottonseed or cottonseed meal. Similarly with cocoanut oil when this constitutes a part of the ration. The presence of the cocoanut oil in the butter affects the Riechert-Meissl number. It is unwise, however, to put too much dependence upon the variations which are noted in the Riechert-Meissl number for the reason that this has been found to vary from 24.44 in August to 32.02 in February.

The butter from cows fed on young fresh grass, clover and other succulent material commonly shows a decidedly higher percentage of volatile fatty acids than butter from cows fed with dry rations.

Doane carried on experiments to determine the cause of mottled butter. It was found that this abnormal appearance occurred more frequently in butter which was imperfectly worked. None of the various samples of butter which were worked for four minutes showed any mottling. Apparently the cause of mottling in this case was the uneven distribution of the salt. The appearance of the mottled butter was not up to market standards but the butter was not in any way deficient in wholesomeness. Occasionally it is believed by other investigators that mottled butter may arise as a result of ripening cream at too high a temperature, the use of excessive amounts of cold water, insufficient washing and unequal temperature.

According to Duclaux butter fat may be affected by the growth of bacteria and molds. The water content of butter infected with molds may increase with age if the butter is exposed and the amount of acid may be diminished simultaneously. In a study of mottled butter in

New York by Van Slyke the conclusion was reached that the appearance is due primarily to the presence and uneven distribution of buttermilk and secondarily to the hardening effect of the salt brine upon the casein in the buttermilk. It was found that the appearance of mottling could be avoided by stopping the churning process when the butter granules had reached the size of rice grains and washing twice with water at a temperature of 35° to 45° F.

Molds of various sorts quite often appear in storage butter, apparently from an infection of tubs which have previously been used for storing butter. The development of molds in such cases may be largely prevented by scrubbing and rinsing the tubs with water containing soda or common salt, or steaming the tubs for five to ten minutes. The development of molds may also be largely checked by rubbing the inside of the tubs with salt immediately before the butter is packed. Still better results are claimed from a procedure recommended by Rogers. This method consists in applying paraffine in a thin coat so as to fill all the cracks in the wood of the tubs. The method entirely prevents the development of molds, gives a neater appearance to the tubs and reduces the loss from shrinkage.

Much time and attention has been given to the study of rancid butter. According to Amthor rancid butter contains some alcohol and an intensive development of a "bouquet" takes place which soon renders the butter unfit for use although its wholesomeness is not affected. Jensen in a study of the rancidity of butter found that two kinds of decomposition may occur in butter fat. An oxidation process may take place during which the unsaturated fatty acids and glycerids are attacked, causing a decrease in the iodin absorption number. Fats may also be decomposed by a hydrolytic process during which they are split up into glycerine and free fatty acids. Jensen maintains that the air plays a direct part in spoiling butter when butter is exposed to a high temperature. The main cause of the rancidity of butter is found in the action of a number of molds and bacteria which cause the splitting up of the fatty acids. Reinmann maintains that the amount of free acid in butter bears no relation to the rancid taste but that a high content of casein and milk sugar is favorable to the development of rancidity.

In Russia, Lidow found that butter subject for long periods to the influence of artificial light changed in color from yellow to white and developed the color and flavor of tallow. The complaints which have been made at times regarding the flavor of canned butter have led to a number of investigations of this subject. Rogers found that the gradual loss of flavor in canned butter is due to the liberation of free acid which in turn is caused chiefly if not wholly by the action of a ferment secreted in the udder of the cow. This peculiar ferment appears not to be secreted except by a small percentage of cows.

Farrington and others have studied the appearance of white spots on butter. This phenomenon was due to the formation of white

crystals quite unlike the mottling of butter and appearing particularly on prints or bricks of butter in a refrigerator. As a rule this appearance is due to maintaining butter at low temperatures in an atmosphere so dry that the water of the brine evaporates leaving salt crystals on the surface of the butter. An examination of boiled or process butter in Philadelphia indicates that it possesses more than 80% of fat and therefore from the standpoint of chemical analysis cannot be considered as adulterated. It is commonly made from rancid or low grade butter by reducing the butter to its original oil, treating it with alkali, freeing it from volatile oils and rechurning it with sour milk.

Occasionally samples of butter are found with a pronounced putrid odor. An investigation was made of a case of this sort in Iowa by Eckles. The putrid butter was found to contain an abnormal number of bacteria which liquefy gelatine. The odor and disagreeable flavor are therefore probably due to the decomposition of the albuminous material in the milk and butter. Occasionally a fishy flavor has been noted in butter as the result of the development of *Oidiun lactis.* This trouble is readily controlled by pasteurizing the milk.

Cheese.—As should be apparent from a consideration of the bacteriology of milk, the harmful bacteria and their products in cheese are largely if not entirely due to the original contamination of the milk. Many studies have been made to determine the extent to which cheese may be injuriously affected by the presence of these organisms. Burri found that Emmenthaler cheese may be greatly injured by the development of a slime-producing bacillus which is sometimes secreted with the milk directly from the udder. In general lactic acid bacteria are the most abundant organisms in cheese while the gas producing bacteria are relatively infrequent. The micro-organisms of different kinds of cheese vary largely. In the manufacture of certain cheeses, specific molds are used to obtain the required flavor and appearance. These molds are of course not of a harmful nature. Thus for example we have the Camembert mold and the Roquefort mold used in the manufacture of the cheeses known by these names. Other species of molds are also concerned in the production of flavors and odors in cheese. The persistence of tubercle bacilli in an active condition in cheese is a matter which has been studied by Harrison and various other investigators. It appears that tubercle bacilli may remain virulent in Emmenthaler cheese for a period of 62 to 70 days, although their virulence was greatly diminished during the last 20 days of the period. In Cheddar cheese bacteria have been found to live for 104 days, but not with sufficient virulence to cause infection, especially when taken into the alimentary tract. Since Cheddar cheese is seldom eaten under four months from the time of its manufacture it is apparent that the tubercle bacilli are almost certain to become quite innocuous before this period or ripening has been completed. Tubercle bacilli have been found in cottage cheese in a condition of virulence sufficient to infect guinea pigs when inoculated into them.

Various other abnormal conditions have been noted in cheese, a part of them being due to bacterial organisms. As a rule, however, these affect the appearance, flavor or odor of the cheese rather than its wholesomeness. In this class of abnormal conditions in cheese mention may be made of so-called pinholes, gassy cheese, swelling—especially in Edam cheese, excessive acidity, and the development of rusty spots, white specks, red coloration and other color changes. Occasionally a blue color is observed in cheese and is believed to be due to the presence of iron in the milk. If spongy or gassy cheese is due to the excessive multiplication of the coli bacillus the product may be unwholesome as human food. The development of molds upon the surface of cheese may be largely prevented by coating the cheese with paraffine and maintaining it in cold storage at a low temperature.

From time to time more or less serious cases of cheese poisoning are reported. The cause of this poisoning has been most thoroughly studied by Vaughan and a review of the literature on this subject has been prepared by the same investigator. In cases of cheese poisoning tyrotoxicon may be isolated, as has already been mentioned in referring to milk poisoning. This substance occurs more frequently in cheese than in milk but has also been isolated from ice cream, cream puffs and other milk products. The physiological effect of tyrotoxicon and the symptoms of poisoning from it have already been mentioned in discussing milk poisoning.

Perhaps the most elaborate account of cheese poisoning is that given by Lochte, who reports that according to some observers cheese poisoning occurs most frequently in November and December and according to others in Summer. More than 300 cases of this trouble was reported by Vaughan in one epidemic in America and the history of other cases have been given in England, Norway, Germany and elsewhere. In many cases of cheese poisoning it has been found impossible to isolate tyrotoxicon or any other substance which could be definitely identified as the cause of poisoning. In order to avoid the occurrence of poisonous cheese, Lochte recommends that only the milk from healthy cows should be used in the manufacture of cheese and that scrupulous cleanliness be observed in drawing the milk and in all the processes it undergoes in the operations of cheese manufacture.

Condensed Milk.—Among the numerous other milk products which have assumed commercial importance, mention will be made in the following paragraphs of some of those which are best known. The manufacture of various forms of condensed milk has been undertaken primarily for the purpose of obtaining a nutritious product containing all of the nutritive constituents of milk in a form which permits long keeping without serious deleterious changes. Newton proposed a patent process for the preparation of condensed milk in England in 1835. Other methods were announced in rapid succession until we now have a number of noted manufacturers of condensed milk who

have their products on the market. The method of Borden was finally worked out in detail in 1866. In the preparation of condensed milk the chief point sought in its manufacture is to work up the milk in as fresh condition as possible so as to complete the operation before any acid develops. Small quantities of acid which may be present in the milk become concentrated by evaporation and may lead to a coagulation of the casein. The prevention of this trouble has been attempted by the use of alkalies in cases where some acid had opportunity to develop in the milk. In the method of preparing condensed milk as proposed by Merz an apparatus is used which holds 5,000 liters of milk and evaporation is brought about at a temperature of 45 to 55 degrees C. during a period of 3½ hours. From ten to twelve parts of cane sugar are added to every 100 parts of milk and the evaporation is carried on until the volume of the resulting product equals one-fifth to one-fourth of the original volume of the milk.

A method has been proposed by Kjeldahl for estimating the amount of sucrose and lactose in condensed milk at the same time. Hyde and others have also proposed special methods for the determination of solids, fat, sugar and other constituents of canned condensed milk. In Germany patents have been issued for the preparation of condensed milk by means of a centrifugal machine. The milk in a thin layer is brought in contact with a cold surface revolved at the right speed to freeze the water out of the milk and at the same time to throw out the condensed product. The amount of cane sugar added to condensed milk is often 40% of the total volume of the product.

Condensed milk when properly prepared seldom undergoes any harmful changes. Bacteria do not thrive in the condensed product and even if they gain entrance to it after the process of condensation is complete the heat applied during the preparation of condensed milk is usually sufficient to destroy any bacteria which may have been present in the milk. Occasionally the formation of gas has been noted in cans of condensed milk as the result of electrolytic decomposition.

Milk powder.—A whole milk powder offered on the market in Austria showed the presence of 20% milk sugar, 28% cane sugar, 22% fat and 17% nitrogenous substances. The tubercle bacilli in milk are destroyed in the manufacture of milk powder by most of the processes which are in commercial operation. The same is true for other bacteria in milk. Apparently a milk powder in which the proteids exist in their natural condition has not yet been put on the market, and this is considered an essential requisite of a perfect milk powder. Probably a whole milk powder answering this requirement is a difficult product to prepare, even if the danger of the powder becoming rancid is obviated. The preparation of a skim milk powder answering all sanitary and culinary requirements is an easier matter. Milk powders have been prepared in Germany by evaporating milk

at a low temperature without the addition of any foreign material and the product is said to keep well.

By evaporation of whole or skim milk in a vacuum at a low temperature Ekenberg succeeded in preparing a fine white powder which dissolves into a milk-like solution with water at a temperature of from 60 to 70 degrees C. This powder has the flavor of milk and when in solution resembles milk in most respects. The keeping quality of the powder is good. It does not mold, ferment, turn acid or rancid and is not hygroscopic. The expense of manufacturing milk powder by this process is about one-third of a cent per liter of milk. One kilogram of the powder will make ten liters of milk of normal concentration. The same apparatus can be used in the evaporation of skim milk and whey. The analysis of milk flour prepared by the method just mentioned shows 36% of nitrogenous matter and 49% of carbohydrates. In Sweden, various milk flours are prepared from both whole and skim milk and the products are readily soluble in water. Similar processes are in common use in France and other countries. It is claimed for milk powders that they are not only readily soluble in water but that they mix with other materials used in preparing various food products more readily than does whole milk in its original state.

Plasmon.—A product known as plasmon or caseon is prepared by drying the casein of milk after the fat has been removed. It is ordinarily a tasteless, odorless, white powder, is readily digested and produces no harmful effects. In the manufacture of plasmon the fat is removed from the milk the remainder of the milk being coagulated, kneaded, and dried at a temperature of 70 degrees C., after which it is ground into a powder.

Miscellaneous milk products.—A number of evaporated milk products have been manufactured on a commercial scale for a considerable period. Nutrose is essentially a combination of casein and sodium in a dry form. Sanose consists of 80% dried casein and 20% of egg albumen. In addition to these desiccated products mention may be made of lactone, which is an unfermented fat-free milk, sterilized and carbonated. Zoolak or Matzoon is a milk preparation in which an intense lactic acid fermentation has been brought about by a special ferment.

One of the most familiar examples of milk products in which an alcoholic fermentation has taken place is koumiss, which is prepared from the milk of mares, camels or cows. In the Orient mares milk is chiefly used in the preparation of koumiss. Lately this product has been made from skim milk with lactose or cane sugar added. Koumiss ordinarily contains 87% water, 1.5% alcohol, 3.7% sugar, 1% fat and .9% free carbonic acid and other constituents.

Kephir is an alcoholic fermentation product of milk containing, besides alcohol, lactic acid, modified milk albumens and peptones.

The so-called kephir grain which is added for the purpose of fermenting the milk consists of a cheese fungus, lactic acid bacteria and *Dispora caucasia.* All of these special milk products have been much advertised as beneficial in the treatment of certain diseases and when properly prepared seldom contain any injurious substances. In addition to the special milk products already described mention may be made of junket, bonny clabber, pap, boiled milk, milk jelly, milk soup, peptonized milk, milk gruel, etc.

Buttermilk.—Mention has already been made of the standard commonly adopted for buttermilk. This product contains all of the constituents of milk. The fat is naturally present only to a small extent and the milk sugar has been largely changed into lactic acid which produces an agreeable flavor in buttermilk. The product should be consumed fresh as it is very susceptible to decomposition. In the case of persons in whom the digestion of fats and peptones is incomplete, buttermilk furnishes an agreeable article of diet. The lactic acid and other bacteria which may be present in it, however, are likely to cause colic or diarrhoea in children. As already stated an artificial buttermilk is in great demand, especially throughout the Southern States. There is so much call for buttermilk that the market cannot be supplied with true buttermilk and resort has therefore been had to the use of skim milk about to sour, which is churned for a few minutes. If some evidence of butter granules is demanded by the customer, Doane states that a small quantity of cream is churned until fine butter granules are obtained, after which this material is added to the sour skim milk. There seems to be no objection to this treatment if care is used in the handling of milk. According to analyses of various samples of buttermilk the fat content ranges from .1% to .4% and the total solids from 5 % to 9%.

Ice cream.—This product is commonly defined as a confection of frozen cream or custard variously flavored. Fruit juices, sliced pieces of fruit or artificial flavoring extracts are extensively used in the manufacture of ice cream. One of the commonest forms of adulteration of ice cream is accomplished by the addition of fillers of which the most important are cereal milling products finely ground, and gelatine. The fillers are added for the purpose of preventing the ice cream from melting too rapidly. Numerous cares of ice cream poisoning are reported from year to year and in most instances this trouble seems to be due to the presence of tyrotoxicon or some other ptomaine in the ice cream. The poisonous product may have been present in the milk from which the cream was obtained or may have developed later during the various processes in the preparation of the final product.

Leben.—This product is prepared by souring and coagulating by means of a specific ferment the milk of buffalo, cow or goat. Leben is used in Egypt, Algeria and elsewhere.

Yaourt or yoghurt is a name applied to milk evaporated by a low degree of heat to 2-3 of its previous volume, and then treated in the following manner: By addition of a small quantity of milk obtained on the previous day the casein of the partly evaporated milk is coagulated in minute particles with the development of a small quantity of alcohol and carbon dioxide. The product is used in Turkey, Bulgaria, Paris and elsewhere. Recently Metchnikoff has recommended it as very healthful on the ground that it tends to destroy or check the development of harmful bacteria in the intestines. Some tests have shown this to be the case, while in others the bacterial flora of the intestines was not affected by the use of yoghurt.

Carbonated milk.—Experiments carried on by Van Slyke and Bosworth in carbonating milk have led to the following results.

"Milk carbonated under a pressure of 70 pounds comes from the bottle as a foamy mass, more or less like kumiss that is two or three days old. It has a slightly acid, pleasant flavor, due to the carbon dioxid, and tastes somewhat more saline than ordinary milk. In the case of carbonated milk pasteurized at 185°F., there is, of course, something of a "cooked" taste. Though the cream separates in the bottle, it is thoroughly remixed by a little shaking as the milk comes from the bottle and there is no appearance of separate particles of cream. All who have had occasion to test the quality of carbonated milk as a beverage agree in regarding it as a pleasant drink. In the case of milk bottled under a pressure of 150 pounds of carbon dioxide; the milk delivered from the siphon is about the consistency of whipped cream, but, on standing a short time, it changes to a readily drinkable condition. From the experience we have had, it would seem that carbonated milk might easily be made a fairly popular beverage.

An important question in connection with the use of carbonated milk is the effect of carbon dioxide gas on organisms other than lactic. While lactic organisms may be retarded in development, might not disease germs present in milk develop and thus make unsterilized or unpasteurized carbonated milk a possible source of danger to health? We have done no work on this point up to the present time, and can only refer to the meager literature on the subject. It should be stated that in all of our work we did not detect any indications of bacterial action so far as could be judged by changes in the flavor of the milk. Foa investigated the action of carbon dioxide gas under pressure of two to five atmospheres upon various organisms and states that it has a checking influence on the development of organisms but does not act on enzymes or toxines. Thus, carbon dioxide under a pressure of four atmospheres checks alcoholic fermentation. Hoffman treated fresh milk with carbon dioxide under a pressure of 50 atmospheres for some hours. Bacteria present in the milk were capable of growth afterwards when the milk was relieved from pressure. This line of work needs thorough investigation and we hope to give attention to it in the near future.

The pressure of gas employed were 70, 150 and 175 pounds per square inch.

The most effective method of treating the milk was to charge it with carbon dioxide gas at the desired pressure in a tank such as is used in bottling establishments in preparing carbonated drinks and then to fill into bottles.

The carbonated milk was kept at temperatures varying from 35° to 70°F. Pasteurized milk, carbonated, kept for five months with little increase in acidity. Fresh, whole milk, carbonated, kept, in one experiment, for about the same length of time.

Carbonated milk makes a pleasant beverage and may find practical use as a healthful drink. It may also be found useful for invalids and children."

CHAPTER XVI.

HISTORY OF MILK INSPECTION.

Since the dawn of history milk has constituted one of the staple articles of diet of all human races. From the numerous references made to milk in poetical, scientific and historical literature of ancient times it is apparent that this food product in a fresh form, or as butter, cheese and various other special products has always been of great importance in the nutrition of man.

In India the chief milk-giving animals are the zebu and buffalo. From these animals milk was obtained and consumed as such or manufactured into butter and ghee as early as 1500 B. C. According to various Jewish writers it is apparent that the Hebrews consumed large quantities of milk from cows, sheep and goats and were fairly well acquainted with the manufacture of butter, although this word has probably been used incorrectly in some of the translations of Hebrew literature. According to Burckhardt the Arabs eat unusually large quantities of butter as an independent article of diet and also use it to an excessive extent on other food products.

Brief references are found regarding the existence of a dairy industry in Egypt as early as 2000 B. C. Apparently the milk used by the Egyptians was largely from goats and sheep. The Greeks likewise in the time of Homer consumed large quantities of sheep and goat milk as well as the milk from mares and asses. Butter was quite extensively used by the Greeks and a cheese was prepared by the use of fig sap and rennet. Aristotle and various other Greek writers refer to the relative composition of the milk of camels, mares, asses and other animals. It was a matter of common knowledge among the Greeks that the flavor and wholesomeness of milk were considerably influenced by the feed stuffs consumed by the cows. Vetches were considered as particularly favorable to the production of large quantities of high grade milk. Strangely enough complaints were made of the unfavorable effect of alfalfa upon milk.

The Romans devised a number of methods for the production of a sour milk product commonly referred to as oxygala. This was prepared by a special process of fermenting sheep's milk. The peculiar constitution of colostrum was also understood by various Roman writers who referred to it as having an unusual density and as showing a spongy nature.

The early literature of the English and other peoples of Northern and Central Europe abounds in references to the use and importance of milk and milk products. In England the county of Cheshire was

famous for its cheese as early as the beginning of the 12th century. Similarly Switzerland became noted for her dairy products in the 13th century and the Holstein region of Holland at about the same period.

During the middle ages a body of superstitious beliefs gradually grew up around the subject of milk and its properties. Various mysterious factors were believed to be concerned in the successful production of butter and cheese and the souring of milk and development of abnormal conditions in it were attributed to witchcraft and other mysterious forces. These superstitious beliefs gradually faded away under the influence of scientific investigation but persisted among a considerable proportion of the common people until within recent years. In fact the supposed influence of thunder storms in the souring of milk may be instanced as an example of such a belief which has persisted until the present day.

In the 17th century milk sugar was definitely isolated and the fat globules of milk were discovered soon afterward. Notable contributions to the composition and properties of milk were made by Gesner in 1549 and Webersky during the same century. In a number of publications in England during the middle of the 18th century specific mention is made of the injurious effect of certain feeds, particularly turnips and cabbage upon the flavor of milk and also of the transmission of drugs and metallic substances from the cow to the milk. The causes of the fermentation of milk were investigated to some extent at the same time and lactic acid was isolated. In the beginning of the 19th century an important contribution was made to the knowledge of milk by Parmentier and Deyeux, who carefully studied the composition and behavior of milk sugar in comparison with cane sugar. Some attention was also given to the specific gravity, freezing point and other physical characteristics of milk.

In all civilized countries a knowledge of the composition and biological characteristics of milk and of the factors which influence its keeping qualities and wholesomeness have preceded by a considerable period the enactment of definite laws controlling the milk supply. It is only natural that this should have been the case since definite facts regarding the possible contamination and unwholesomeness of milk must first have been worked out before any demand would have arisen for the supervision of the milk supply. In general the demand for the regulation of the milk supply has arisen first in large cities in which, as their size increased, the difficulties of furnishing wholesome milk according to the old methods became greater and greater. The first point concerning which laws were demanded was the matter of adulteration of milk and in many of the early laws this was the only point mentioned. If we may believe that the early milk inspection laws reflected the conditions which prevailed in the milk business, the extent of dilution of milk with water became at some time or other an exceedingly serious matter in nearly all large cities.

In England the first milk law was passed in 1860, and had to do only with the adulteration of milk. The law prohibited the dilution of milk with water or the use of other substances for the purpose of concealing dilution. The first attempt in England to regulate in a general way the city milk supply was put on foot in 1866 under the direction of the Aylesbury Dairy Company, an example of numerous other similar institutions which have developed as necessary growths in sanitary regulation of municipal milk supplies. Before such companies were established the milk supply of all large cities came from a large number of milk dealers and dairymen who owned a few cows kept under greatly varying conditions. The quality of the milk therefore varied greatly at different seasons and striking differences were noted in the composition and wholesomeness of the milk of different dealers. The establishment of large dairy companies, often of a co-operative nature, was therefore recognized as an absolute necessity in securing a tolerably uniform quality for the milk supplied to any given city. At the beginning of the existence of the Aylesbury Dairy Company, two grades of milk were established, one of which was considered suitable for immediate consumption in the fresh state, while the other was held to be unsuitable for such use and was churned for the production of butter. The plan adopted by the Aylesbury Dairy Company was based on that of a similar company known as the Willowbank Dairy, which was started in Glasgow in 1809.

As already indicated similar sanitary commercial institutions for the control of a milk supply were established in various other countries at about the same time with the Aylesbury Dairy Company in England. Thus in Hamburg the Farmers' Co-operative Dairy Company was established in 1863, a similar one in Lübeck in 1879, in Berlin and Vienna in 1891 and in various parts of Denmark and other Scandinavian countries in 1881 and 1884. The purpose of the present union of Berlin milk dealers is essentially the same as that of the companies already mentioned. The Central Co-operative Creamery Society of Budapest began its existence in 1883 on a small scale and now covers two acres of ground and handles about 9,000 gallons of milk daily. The results which this society seeks to accomplish are the supply of the best possible milk to consumers and the maximum profit from the milk to farmers. So-called control unions have been established among dairymen very extensively in most parts of Europe. Of these unions there are 204 in Sweden, 120 in Norway, 40 in Finland, 3 in Holland, 2 in Scotland and 5 in Austria. The purpose of the control unions is to promulgate by co-operative efforts among dairymen information and improved methods regarding the feeding and care of dairy cows and the care and handling of milk in order to produce a large supply of pure milk at a reasonable profit for the dairyman. A great amount of good has been accomplished by the control unions along this line.

In all of the English colonies some legislative attention has been

given to the control of the milk supply. Milk inspection is not everywhere put on an independent basis and therefore the results are not always as satisfactory as could be desired. In New Zealand, stock inspectors have also the duty of taking samples of milk for analysis and examination by chemical and bacteriological experts and also of inspecting dairy cows and premises.

In Germany the only general imperial law relating to milk inspection and holding good for the whole empire is that of 1879 on foods, condiments and manufactured articles. This law forbids the adulteration or use of harmful preservatives in all kinds of food products and has naturally been held to apply to milk. Complaints have occasionally been made by veterinary and sanitary authorities in Germany that further general legislation on the subject of milk inspection is necessary. Other authorities, on the contrary, have held that the milk supply of cities cannot be regulated by an imperial law in greater detail than is now accomplished by the law on foods and condiments. The conditions vary so much in different localities that each city must apparently regulate the matter independently. An imperial commission however has a general supervision of local regulations of milk inspection in German municipalities. In Berlin the specific gravity of the milk is determined and the fat percentage by a chemical analysis. Milk of diseased cows, especially those affected with foot and mouth disease, is not admitted for human consumption. In Bromberg, lactometer tests are made by police officials. Market milk is required to contain 12.25% of total solids. Tests are also made for the percentage of fat and for possible adulteration. In Bromberg as well as in all other cities of Germany the milk of cows suffering from contagious mammitis, enteritis and septic metritis is excluded from the market.

According to a ministerial circular decree of 1899 with modifications announced in 1900, the traffic in fresh, boiled, sterilized or sour milk and buttermilk in Prussia is under police supervision. Milk may be offered on the market in the form of whole milk, half milk, skim milk and buttermilk, each quality of milk being properly labelled. Whole milk must show 2.7% of fat, half milk 1.5% of fat and skim milk .15% of fat. The specific gravity of whole milk may vary between 1,028 and 1,034, half milk between 1,030 and 1,036 and skim milk between 1,032 and 1,037. The minimum permissible fat content of cream is 10%. Boiled milk is understood as having been brought to a temperature of 100 degrees C. or maintained at a temperature of 90 degrees C. for 15 minutes.

The circular decree prohibits the admission to the market of milk obtained just before calving or within six days after calving; the milk of cows affected with anthrax, black leg, rabies, cow pox, jaundice, dysentery, blood poisoning and inflammations of the udder; the milk of cows which are being treated with various drugs, such as arsenic, opium, eserin, etc.; the milk of cows affected with mammary tubercu-

losis; all milk which contains foreign bodies including ice and chemical preservatives; all blue, red or yellow milk and milk contaminated with molds or blood clots or showing changes due to bacterial action. The milk of cows which are affected with foot and mouth disease or tuberculosis cannot be used until after sterilization.

The circular decree in question specifies in detail a set of rigid conditions under which milk for children must be produced.

In Copenhagen, The Milk Society Trifolium has assumed a general supervision of part of the city supply of milk. A physician and a veterinarian constitute a committee for the decision of points of sanitation which may arise in connection with the milk supply. The Trifolium Milk Society is under obligation to this committee to furnish milk which contains at least 3% of fat. Milk intended especially for children must be produced on premises on which approved sanitary methods are in vogue and from cows free from tuberculosis and other dangerous diseases and repeatedly tested with tuberculin. The society agrees to furnish veterinarians who shall work under the direction of the control committees consisting, as already stated, of one physician and one veterinarian. On the premises from which milk is obtained it is necessary that a veterinary inspection be made from time to time and that all diseased animals be isolated and their milk excluded from the general supply coming from the herd. Cows purchased by dairymen from outside sources must be inspected by a veterinarian under the supervision of the control committee before the milk is allowed to be mixed with that of the herd. Detailed specifications are also furnished regarding the required health of milkers, the feeding stuffs given to the cows, particularly turnips, distillery refuse, brewers' grains and other feeds which may affect the quality or flavor of the milk and regarding the methods of milking and handling the milk until it reaches the consumer.

In Italy the dairymen are required to give notice of their intention to open a dairy and to furnish milk for city use. The premises and cows are then inspected and also all details about the premises, even the bedding and milk room. The latter must be as far as possible from the stable. The dairymen are required to give immediate notice of sickness in any of the cows and the milk from such cows cannot be offered for sale until a veterinarian pronounces it wholesome. Only suitable and wholesome feeding stuffs are permitted to be used. The Italian milk regulations forbid the sale of milk from diseased cows or from cows improperly fed, as well as adulterated milk or milk showing any of the common abnormalities.

In Paris a strict veterinary inspection is made of dairies for the purpose of excluding from the market milk from cases of mammitis and other dangerous diseases in cattle. Veterinary inspectors also have the duty of examining and passing upon the general sanitary conditions of the premises. A permanent commission for the prevention of tuberculosis takes cognizance of all tuberculous cows and issues

instructions regarding the disposal which shall be made of these cows and their milk.

Essentially the same stages have been passed through in the development of the dairy industry in this country as have been noted in Europe. With the concentration of large masses of population in the chief cities of the country the problem of furnishing an adequate milk supply of a wholesome nature became more and more complicated. The difficulties connected with this situation were appreciated by both the producers and consumers but as has happened in the manufacture and sale of nearly all other food products much difficulty was experienced in securing an effective co-operation between the producer and the consumer to the end that better milk might be supplied. The first complaints which were heard from the consumers regarding the quality of milk related largely to adulteration, especially with water, the use of preservatives and the presence of unnecessary quantities of filth. Naturally, therefore, the first laws passed for the control of the municipal milk supplies contained chiefly clauses prohibiting the adulteration of milk and compelling the observance of more sanitary methods by the dairymen. In many instances these laws were quite ineffective for the reason that no provision was made for the appointment of milk inspectors. Where no inspectors were provided for, the consumer had no recourse except to complain to officials who had to deal with other sorts of nuisances and to attempt to get redress in that manner.

So far as we have been able to determine, the first law for the control of the milk supply was passed in Boston in 1856. This law merely prohibited the adulteration of milk. A new law passed by the Massachusetts Legislature in 1859 provided for inspectors and the office of the Boston Milk Inspector was established on August 10, 1859. The law under which this office was established was again revised in 1864 and clauses were added forbidding the use of distillery refuse as feed for dairy cows and also forbidding the use of milk from diseased cows.

There has been a legal foundation in New York for the analysis of milk and testing for fat since 1869. In 1870 the inspectors' reports in New York City indicated that the average market milk contained one quart of water to each three quarts of milk. At that time, therefore, the inspectors were largely occupied in detecting adulterations.

At the present time an unusual amount of attention is paid to the sanitary condition of the milk supply of Boston. The State Board of Health of Massachusetts makes a veterinary inspection of dairies which supply the city with milk. The veterinary inspection of the dairies takes account of the condition of the cow stables, their construction, means of ventilation, nature of floor and stalls, quality of bedding, disposal of manure, location and storage of feeding stuffs, general conditions as to cleanliness, source of water supply, distance

of water supply from the stable, direction of the ground level from the source of water supply, condition of cows' udders, temperature of the milk, washing of dairy utensils, use of ice, length of the haul of the milk to the station and condition of the milk at the time of delivery at the station. In addition to the veterinary inspection of the cows and dairy premises, the milk is subjected to chemical and bacteriological tests after it has arrived in Boston. The bacteriological standard adopted allows a maximum of 500,000 bacteria per c.c.

The milk supply of New York varies considerably in its quality but the recent continued campaign for pure milk in that city has led to a great improvement in the average quality of the milk delivered at the metropolis. A considerable amount of pressure has been brought to bear upon dairymen by the milk dealers of the city who are supported by an association of physicians in testing the milk and inspecting the dairy premises. As stated by Whitaker and others milk produced from healthy cattle under approved sanitary conditions is certified by an association of physicians, and since certified milk commands an extra price an increasing number of dairymen have improved their premises and methods so that they may produce such milk. In some instances where the milk is carefully drawn, immediately cooled at 38 degrees F. and handled under sanitary conditions it reaches the market with a bacterial content between 1,500 and 5,000 per c.c.

In Philadelphia, the Philadelphia Pediatric Society is especially interested in securing a supply of pure milk for children. This society appointed a committee in 1898 to investigate the problem of improving the municipal milk supply. An examination of the dairy premises and the milk furnished by dairymen was made once per month. Milk intended for children must come from healthy cows in well cleaned and ventilated stables, must show a neutral or faintly acid reaction, not less than 3.5% of fat, and must be free from all foreign matter and chemical preservatives. It is also required that the milk shall not contain pus nor pathogenic bacteria nor more than 10,000 bacteria of any kind per c.c.

The milk inspection division of the Department of Health in Chicago was established in 1892. A license was required for all dairymen, and chemical standards were established for market milk. An inspection of the milk supply for Chicago has become more and more strict and efficient in recent years, partly as the result of the occurrence of serious epidemics of scarlet fever and diphtheria which were traced apparently to the milk supply.

The necessity for a general campaign for pure milk has become more and more apparent throughout the country during recent years and has led to the enactment of legislation in all of the States and Territories and to the establishment of municipal ordinances regarding milk in nearly all of the cities throughout the country.

In some instances these laws are highly defective and fail to provide

the proper officials for their enforcement or fail to require a sufficiently rigid inspection of the milk. It is obviously an inadequate protection of the public merely to examine samples of milk which may be offered upon the market for the purpose of determining the chemical composition and bacteriological content of these samples. It has repeatedly been shown that where both temperature and bacterial standards are set up for milk it is necessary to make use of both of them in order to reach any just conclusion regarding the quality of the milk. Thus it may well happen and often does happen that adequate refrigeration is not applied to milk during its delivery to the market but that despite the absence of refrigeration the milk reaches the market relatively free from bacteria. This indicates that the milk was drawn and handled with special care and under satisfactory conditions. On the other hand numerous samples of market milk are found in which the temperature is below 50 degrees F. but in which the bacterial contamination is enormously high. This in turn indicates that filthy habits or carelessness have contributed to the contamination of the milk and that the use of ice has not been sufficient to obscure this contamination.

It has come to be recognized that a proper system of milk inspection should include the registration of all dairies furnishing milk to a given city, the veterinary inspection of cows, barns, milk rooms and other features of the dairy premises at least once a month, the eradication of tuberculosis from dairy herds, the branding of condemned cows so that they may be readily identified, the requirement of wholesome feeding stuffs for all dairy cows, the careful and thorough cleansing of all milk utensils, the immediate application of refrigeration to milk as soon as it is drawn, chemical and bacteriological examinations of milk at the city terminus, severe penalties for the violation of milk laws and public reports on the conditions observed at each dairy and on the bacterial count determined in samples of milk.

As a result of the agitation which has long been going on in the District of Columbia for the improvement of the milk supply, a commission has been appointed which, it is believed, receiving as it does the active support of the President, the Board of Health, the Department of Agriculture and other bacteriological experts, will put into operation one of the most efficient systems of milk inspection which has yet been devised. This system as at present outlined rests upon the solid foundation that an efficient milk inspection must begin at the farm where the milk is produced and must follow the milk through all of the processes of handling until it reaches the consumer.

CHAPTER XVII.

BIBLIOGRAPHY OF MILK INSPECTION.

The references which have been selected for this list include those books and articles consulted in the preparation of this volume which are believed to be of most value to the milk inspector and dairyman. It is far from complete on any subject. The bibliography of milk inspection in a broad acceptation of the term is immense, and has already been made accessible. Rothschild's Bibliographia lactaria and the supplements published to date include nearly 11,000 titles of articles. Perhaps the best selected bibliography of the sanitary aspect of milk is to be found in "Milk and its relation to the wealth and health of the people" published in Hamburg in 1903. A large bibliography is also given in Snyder's Dairy Chemistry. The following references have been arranged according to the chapters to which they naturally belong, but many books and articles, as indicated by their titles, cover several chapters.

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